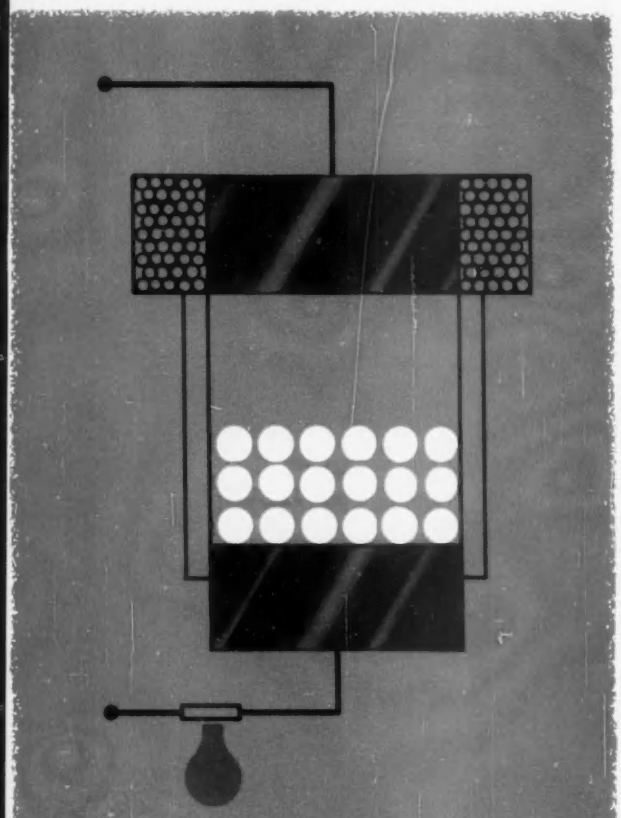
Control ENGINEERING

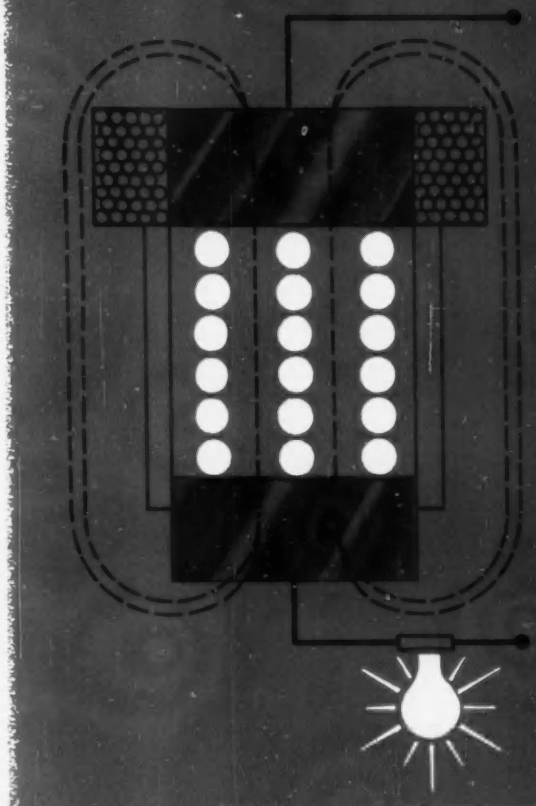
INSTRUMENTATION AND AUTOMATIC CONTROL SYSTEMS

A McGRAW-HILL PUBLICATION

60 CENTS

FEBRUARY 1958





MULTIPLE-BALL RELAYS

—Newest Components for Reliable Switching

if you

record . . .

- TEMPERATURE • POWER
- FLOW • SPECIFIC GRAVITY
- GAS ANALYSIS

THE LIBRASCOPE

direct reading

COMPUTING LINEAR INTEGRATOR

will present automatic totals or averages of recorded data accurately, quickly.

Where there is a need for flow totalization, temperature recording or area computation by direct reading or remote reading, Librascope Linear Integrator can be used to advantage on standard or miniature chart recorders. The only requirement is that the variable to be integrated or averaged be presented as a shaft position or deplacement.

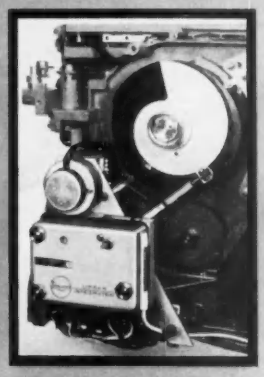
Model 25 is a ball disc integrating mechanism assembled with a counter and an electrical pulse output switch for remote recording.
Librascope's carefully engineered design is streamlined, compact and easy to install.

complete data bulletin available upon request

GPE LIBRASCOPE

A SUBSIDIARY OF GENERAL PRECISION EQUIPMENT CORPORATION

Librascope, Incorporated • 808 Western Ave. • Glendale, California



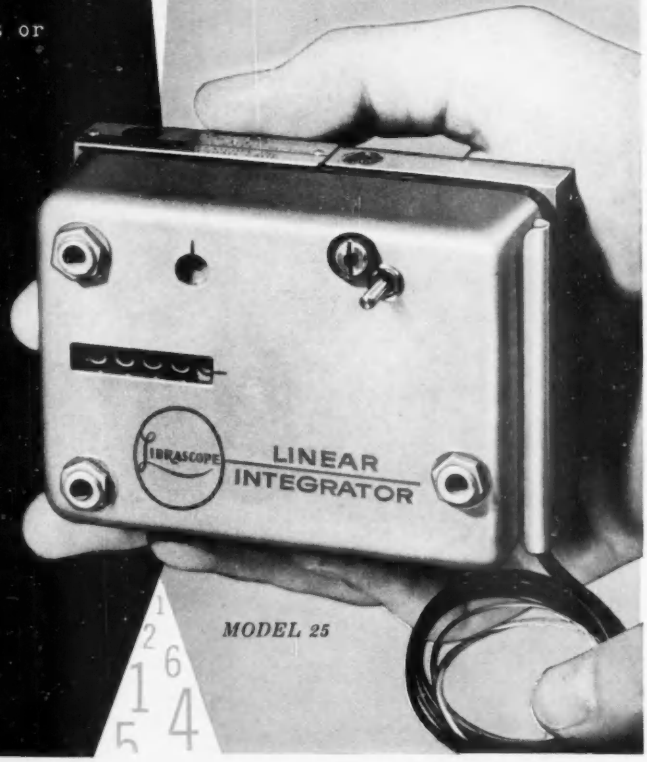
APPLICATION

Mounted on Strip Chart Recorder, the Model 25 Librascope Linear Integrator in this position accepts the output of the transducer or the recorder plus motion as an input.

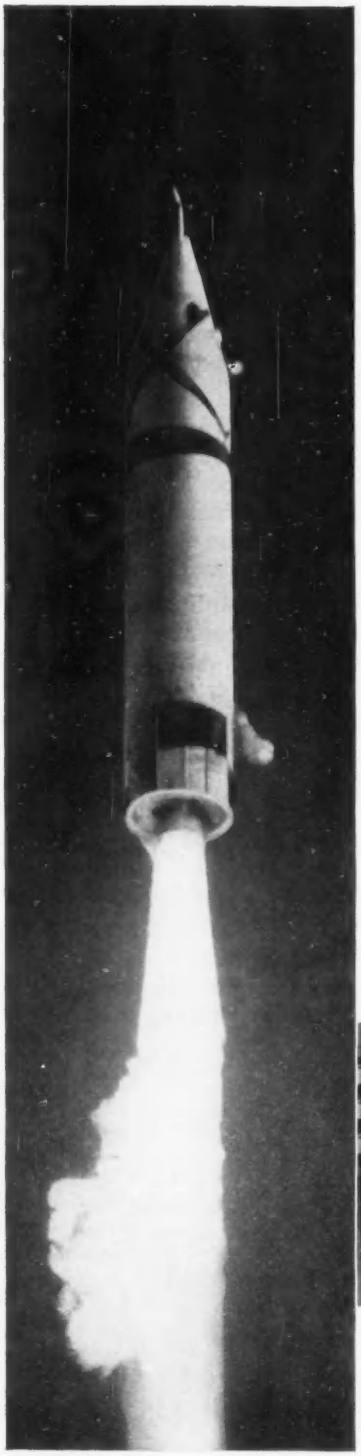
PERFORMANCE SPECIFICATIONS

Model 25

Linearity (% of full scale)—0.2
Repeatibility (% of full scale)—0.05
Range (Percent)——10 to +110
Full Scale Travel—23°, 28'
Response—Instantaneous
Torque—Time Shaft (in./oz.)—0.50
Input Shaft (in./oz.) maximum—0.35
Temperature Range—
−45°F to +150°F
Outputs: Mechanical Counter and Switch Closer For Remote Pulse
Weight—1.5 (lbs.)



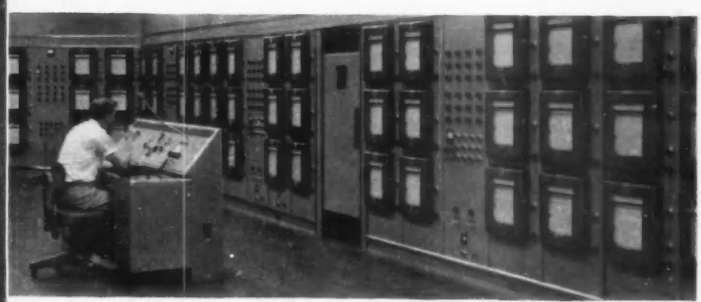
MODEL 25



When the stakes are high . . .

"Accuracy, reliability and versatility are the major considerations for instrumentation here at Redstone," says Fritz Weber, Chief of the Instrumentation Test Section, Army Ballistic Missile Agency. "During tests that may involve hundreds of thousands of dollars in equipment, supplies and manpower, a failure of the data recording equipment can result in a total loss of the run.

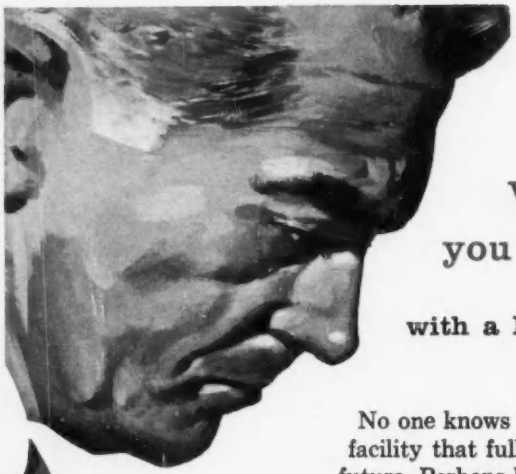
"In our strip chart recording room, we have over a hundred L&N Speedomax G modified adjustable instruments. All are equipped with retransmitting slidewires so that data can be fed into a Millisadic data system for storage and transmission to IBM equipment. Recorders are so equipped that they can be controlled from a central console. There, the operator can select the test site from which data is to be received and the method of data handling to be used. Before a test is started up, all 132 recorders can be standardized by a single button."



Vital data on Jupiter and Redstone Missile assemblies are supplied by 132 Speedomax G precision Recorders. As part of an exhaustive testing program, these data help guide ABMA's scientists in missile-firing.

"New Horizons", *L&N's Tech. Pub. ND46 gives data on circuitry, and performance characteristics of Speedomax instruments. Get a copy from your nearest L&N Office or from Leeds & Northrup Co., 4918 Stenton Ave., Phila. 44, Pa.*

LEEDS NORTHRUP
Instruments Automatic Controls • Furnaces



Why crystal gaze...
you can start closing loops now

with a Beckman / 112 Data Processing System

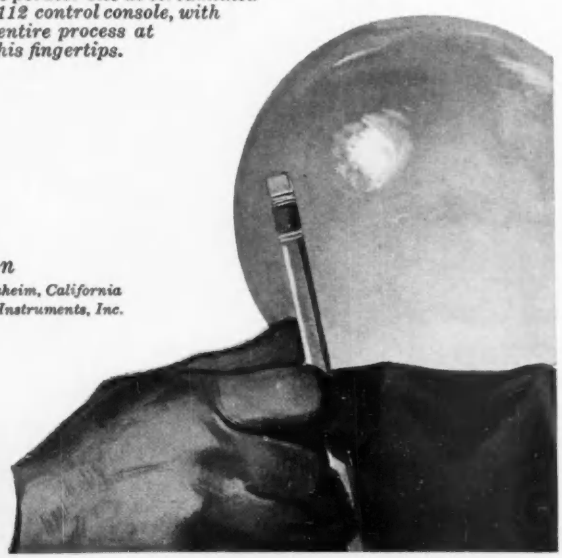
No one knows better than the operator of an on-stream process facility that fully automatic, closed-loop controllers are a part of his future. Perhaps he is already using data processors, or even closed-loop controllers of sorts—probably decentralized, multiple-instrument installations of analog equipment. No doubt he would like something better. He has been promised a whole lot more.

He has been promised accurate, reliable, fully integrated systems—closed-loop, digital controllers that will turn operational nightmares of today into the production dreams of tomorrow. And no doubt he will get them, but the question is *when?* Can he afford to wait?

He doesn't have to wait. He can swap his crystal-ball system of tomorrow for a mirror reflection of his processes today. An accurate, reliable, fully integrated data-processing system—compatible with automatic controllers—is already a "hardware" reality. The Beckman 112 System is at work in the process industries now. Combining the best features of analog and digital methods, the 112 is on the job around-the-clock—monitoring stream variables, giving off-limit warnings, performing the mathematical computations for continuous control, and producing digital readout in readily usable form.

For information on how Beckman Systems Division can provide you with a field-tested system to meet your process needs now, write for Data File 3D-12-46.

Operator sits at streamlined 112 control console, with entire process at his fingertips.



Beckman® / *Systems Division*

325 N. Muller Ave., Anaheim, California
a division of Beckman Instruments, Inc.

Control ENGINEERING

FEBRUARY 1958
VOL. 5 NO. 2

Published for engineers and technical management men who are responsible for the design, application and test of instrumentation and automatic control systems

Continued on next page ▶

Control ENGINEERING

STANFORD R. OVSHINSKY—inventor of the ball-type relay revealed for the first time on page 82—started his career as a machinist. But the urge to be his own boss led him to organize three companies—all formed since 1944, all successful financially, and all concerned with the development of special machinery and machining techniques. The ball-type relay resulted from an open-minded study of methods of varying the resistance of an electrical conductor. Stan felt that if he could develop "macroscopic molecules" he could produce an essentially solid conductor with variable resistance characteristics. The multiple-ball devices are the result. Incidentally, Stan is an acknowledged expert in neurophysiology and has had papers published in the leading medical journals.

PRINT ORDER THIS ISSUE 35,376

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- Frequency measurements at 0.1 v rms over 0 cps—10 mc, without heterodyning or plug-ins
- 10 operating functions and three input channels for maximum application flexibility
- 7-place direct digital readout—no meter indicators
- Priced at only $1975.00

Beckman/Berkeley Model 7370 Universal EPUT® and Timer

BRIEF SPECIFICATIONS

Model 7370

Functions:
E/UT, E/UT × 10, SCAN, COUNT, TIM, PER, PER × 10, E/B, E/B × 10, E/B-A, (TEST)

Ranges:
Frequency: 0 cps to 10 mc
Period: 0 cps to 3 mc
Time Interval: 0.3 μsec to 10^7 sec
Ratio: 1 to 10^7 from 10 cps to 10 mc

Time Bases:
0.1 μsec to 10 sec in decade steps

Accuracy:
±1 count ±oscillator stability

Oscillator Stability:
3 parts in 10^7 per week

Price:
$1975.00 F.O.B. Richmond, California

Developed specifically to meet the test instrumentation needs of today Model 7370 is a completely self-contained precision instrument capable of handling a broad range of frequency, frequency ratio, and time interval measurements easily, dependably and with extreme accuracy. The most modern counter-timer obtainable, it features three input channels for greater application flexibility; field-proved components; advanced circuitry; modular chassis construction; binary coded output from all DCU's for driving auxiliary equipment such as a digital recorder.

Half the size of conventional instruments of its type, Model 7370 weighs only 62 pounds. Input impedance is 1 megohm; available output frequencies, 1 cps to 1 mc; accuracy, ±1 count. Built-in self-test facility checks correct operation of all frequency dividers and DCU's. Optional Standard Modifications, including provision for flow meter input, expand the laboratory and in-plant utility. Controls are functional, and so simple that non-technical personnel can be readily trained in their use.

Complete technical details on the Beckman/Berkeley Model 7370 Universal EPUT and Timer are available on request. Write to Department L2.

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150

SHOPTALK

Something New Has Been Added

With this issue, a new department, "What's Available in Reprints" (see page 190), makes its debut. Despite a large and steady demand for CtE reprints, there has been little attempt to make known just which ones were available. From now on, however, all reprints will be briefly described and a convenient form provided for ordering them.

The reprints will be selected in various ways: special reports printed originally as a separate form (such as the positioning systems report, page 99); groups of interrelated articles (such as the four modulator articles that appeared in the Aug., Oct., Nov., and Dec. '57 issues); and important reference-type individual articles (such as the *Basic Digital Series* articles). Each reprint will be a valuable adjunct to your files.

The High-Speed Age of High-Speed Computers

When Dow Chemical's Ascher Opler (see page 19) flew into New York for a week's tour of duty at IBM's Computing Service Center, he invited CtE Editor Bill Vannah to "watch" the problems go through the 704. The problems to be solved were necessary steps toward the computing control of the chemical composition and the physical properties of synthetics. Bill reports:

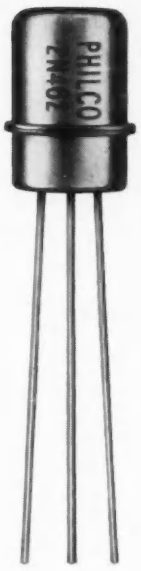
"I found Ascher 'frozen' to his desk because his tapes were due to go on the 704 any minute. Coffee and explanations of the waiting-line procedure for scheduling the computer melted the time until the phone rang to tell us we were 'fluid' and that we should hasten to the 'ready room'. There we picked our tapes out of a rack and nervously discussed whether the computer would finally start talking to us, rather than continuing to find fault with our program. Three minutes before we were to go on stage, we were ushered into the control center. There we threaded our tapes and waited for the previous group to finish.

"At the start signal, Ascher hopped about, throwing switches and giving me unintelligible instructions. While in the process of settling down against the printer to wait out the computation, the first problem was completed and we were into the second one. Soon it was 'in the loop', which I found meant that the computer had found a solution to the first part of the problem and was repeating it. Next it 'cleared' the memory and went on. For a while the printer kept up with the computer's progress, but soon we had to 'dump' the core memory onto an auxiliary tape. After the third solution, our ten minutes were up and off we went to print out the data that had been dumped on tape."

The center works around the clock, and the do-it-themselves users go on when the computer is available. Split-second scheduling at $11 per minute keeps the waiting line moving. Bill was glad to get back to magazine deadlines.

FIRST FROM PHILCO

New Bilateral Transistor!



PHILCO 2N462

Bilateral alloy junction PNP transistor with controlled pulse response. (Shown greatly enlarged)

Outstanding Transistor Performance With Current Flow IN EITHER DIRECTION!

This transistor represents a new concept in semiconductor electronics and is available in production quantities. Emitter and collector are completely interchangeable. Performance characteristics meet the same specifications in either direction of current flow.

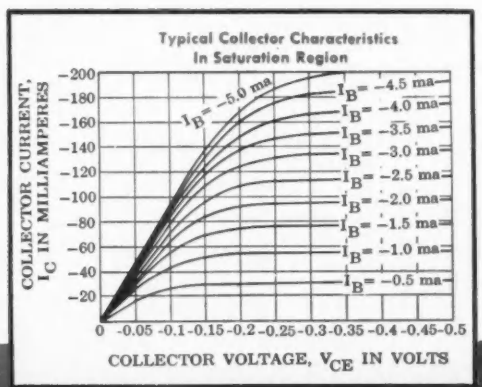
The new Philco 2N462 features high current (200ma), high gain (typical beta 45 in each direction), high voltage (40v), low saturation voltage—with controlled turn-on and turn-off times.

This revolutionary new transistor is exceptionally well suited to complementing circuitry, and for use in circuits where reversing the direction of the controlled current is desirable. The 2N462 has been used successfully in computers, communications equipment, multiplexing devices, and for bi-directional switching and phase detection systems.

Perhaps this new transistor can help solve a specific design problem for you. Our engineers cordially invite your inquiries.

Make Philco your prime source of information for all transistor applications.

Write to Lansdale Tube Company, Division of Philco Corporation Lansdale, Pa., Dept. CE-258



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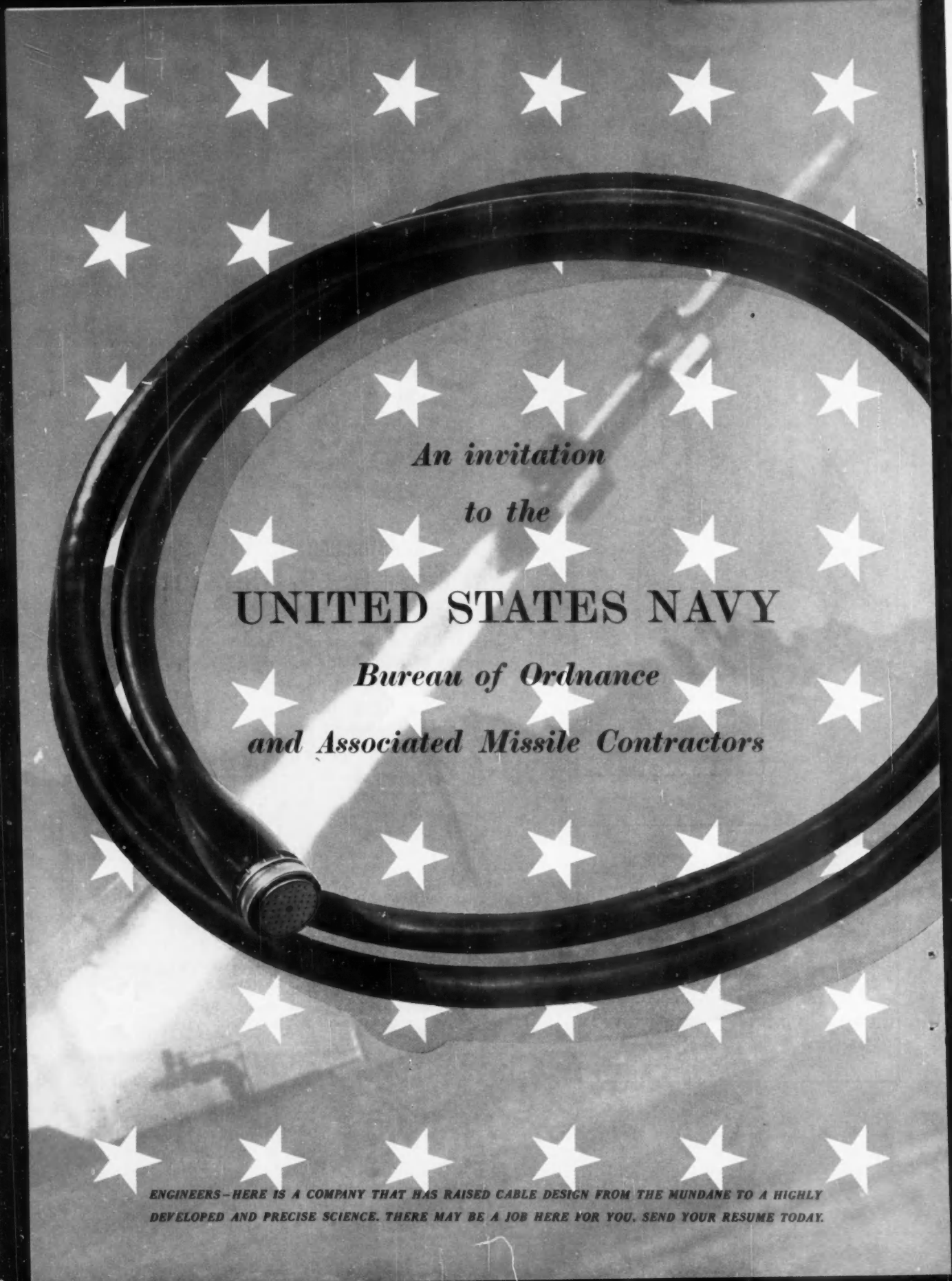
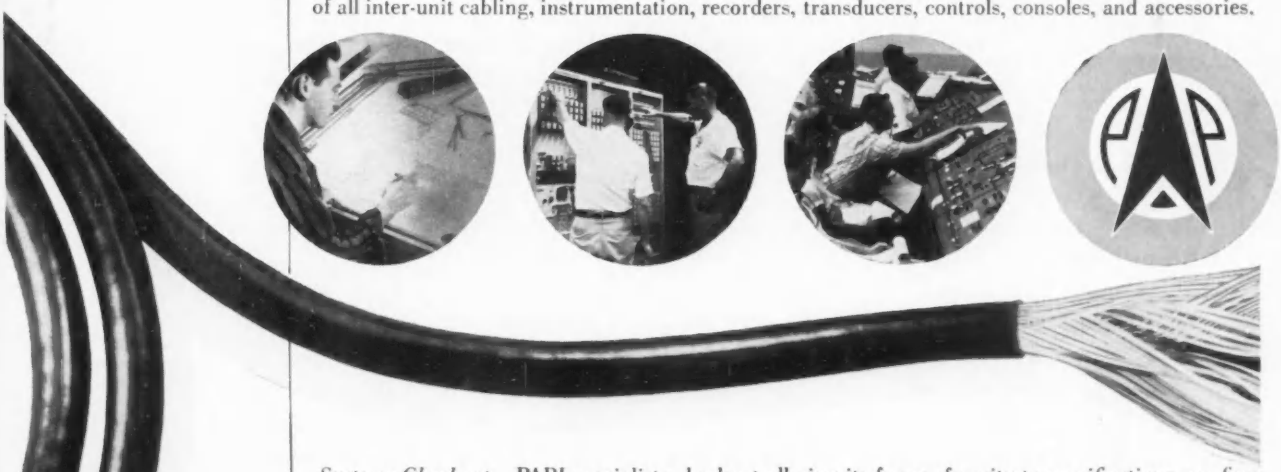
TRANSISTOR CENTER U.S.A.


An invitation
to the
UNITED STATES NAVY
Bureau of Ordnance
and Associated Missile Contractors
ENGINEERS–HERE IS A COMPANY THAT HAS RAISED CABLE DESIGN FROM THE MUNDANE TO A HIGHLY DEVELOPED AND PRECISE SCIENCE. THERE MAY BE A JOB HERE FOR YOU. SEND YOUR RESUME TODAY.

INVITATION: This is an invitation to utilize the missile systems engineering services of Pacific Automation Products, Inc., on current and upcoming Navy missile programs.

SPECIFIC SERVICES: PAPI offers the following services in the cabling and activation of missile test and launch facilities: *Systems Design* — working from schematics, PAPI design engineers will determine every conductor that is needed to link block houses, control centers, terminal rooms, and stands or platforms. Cables are designed to effectively accommodate these conductors, and include break outs, connectors, and accessories. *Systems Fabrication* — cable assemblies leave our plant in ready-to-install condition, with rigorous quality control procedures governing every step of the fabrication process. *Systems Installation* — PAPI's experienced personnel and proven methods are utilized in field installation of all inter-unit cabling, instrumentation, recorders, transducers, controls, consoles, and accessories.



Systems Checkout — PAPI specialists checkout all circuits for conformity to specifications, confirm the operation of each instrumentation system, and validate the fire and launch control functions. *Systems Documentation* — working drawings of the entire installation are supplied in approved form.

QUALIFICATIONS: PAPI is an efficient organization of 600 persons, 130,000 square feet of floor space house engineering and production capacity to meet any workload. Because PAPI cable components have been used in Navy projects, including Vanguard and the Regulus missiles, you know our product to be reliable.

PAPI systems engineering services have been used on other missile programs with these results:

- ▶ All sites and facilities are being completed on or ahead of schedule.
- ▶ 16,000 cable components are now in service, with no malfunctions due to cabling.
- ▶ Costs have been far less than predicted.
- ▶ Superior designs and simplified operational characteristics have marked each facility.

Of special interest will be PAPI's Water Tight cable, which salt water cannot penetrate at 500 fathoms. It is ideal for underwater umbilicals.

Because the mechanical and environmental capabilities of PAPI cables often permit great simplification in the design of missile facilities and savings in cost, an early visit by PAPI with site or facility builders is recommended.

CONCLUSION: PAPI's engineering staff includes men with outstanding experience in every phase of the missile business. It is no accident, therefore, that we are the "take charge" sort of people who can take full responsibility for providing the services described in this message. We hope that you will accept this invitation and plan to utilize PAPI's great practical knowledge and experience in missile facility cabling and activation.

Arthur P. Jacob

ARTHUR P. JACOB, EXECUTIVE VICE PRESIDENT

PACIFIC AUTOMATION PRODUCTS, INC.

1000 AIRWAY, GLENDALE 1, CALIFORNIA *Phone: CHapman 5-6871 or Cltrus 4-8677*

FEEDBACK

FORUM ON STANDARDS

Published under this title in the Feedback section of the October '57 issue, a letter from R. B. Colten, Process Development Section, General Motors Technical Center, Detroit, Mich., pointed out how JIC standards could be improved to assure minimum quality levels in manufactured industrial control equipment. He reported that an electronics committee within General Motors is preparing suggested new standards which it will recommend for incorporation into current JIC standards. Here are samples of invited discussion of Mr. Colten's letter.

Let's add, not replace . . .

To the Editor—

To obtain a wide acceptance of a standard requires a wide understanding of that standard. Making two standards where one now exists decreases such understanding and, with the advent of revisions, could lead to contradictions, particularly on combinations of electronic and industrial control.

Let us hope that any new standards on electronic control are supplemental to, and indicate the departures from, the Industrial Control Standards. This should eliminate throwing the burden on the individual of deciding which standard to follow.

It is unfortunate that in the examples given in Mr. Colten's paper [Mr. Colten's letter was a sequel to a paper he presented at the 21st Westinghouse Machine Tool Electrification Forum last April], two factors are outstanding. One is that many of the faults would not have been present had the manufacturer followed existing Industrial Control Standards, and second, it is almost impossible to legislate neatness. The main weapon against this is not to purchase from producers of this inferior type of work.

It would appear that the main advantage of an industrial electronic standard would be to force the production of industrial type electronic components just as the Control Standards have given rise to superior disconnect switch mechanisms, oil-tight push buttons, wiring ducts, etc.

A. L. Krause
Brown & Sharpe Mfg. Co.
Providence, R. I.

. . . but don't try to do it alone

To the Editor—

I certainly agree with you that the formulation of new standards is always a controversial matter, and I doubt that there can ever be any standard in the area of industrial electronic equipment that will be completely satisfactory to all builders and users alike. I do feel that the JIC standards for hydraulic equipment, electrical equipment, and press definitions were certainly necessary and have more than achieved their purpose.

At the present time there are two major standardization efforts under way in the field of electronic equipment. The Aircraft Industries Association, through its Equipment Committee and its subcommittee for numerical control, is preparing performance standards for numerically controlled equipment. The Electronic Industries Association, formerly RETMA, is extremely active in both design and performance standards for electronically controlled equipment. There is close liaison between committees of both of these associations.

In my opinion, the most effective and economical method of establishing design standards for industrial electronic control is by joint action, and I think that JIC, or any other organization, should work with the EIA groups rather than attempt to issue separate and probably nonconforming standards.

George E. Kinney
Hughes Tool Co.
Culver City, Calif.

More next month. Ed.

Milli scores decisively over micro

To the Editor—

In the Oct. '57 issue of Control Engineering we read your very interesting note (page 36) about the new electronic digital computer named the

"Mercury", which has been put into production by Ferranti, Ltd.

We take, however, the liberty to draw your attention to the fact that the speed this note gives for division (3.5 microsec) is in contradiction with the further sentence, "Although the machine divides at relatively slow speed. . . ." Probably this is a typographical or printer's error: the actual speed for division amounts to 3.5 millisec.

But there is one more thing: division on this computer is performed by program. So it seems better to put this characteristic among the listing of the typical subroutine speeds.

Joseph L. F. De Kerf
N. V. Gavaert Photoproduction,
Mortsel (Antwerp),
Belgium

Technician requirements too high

TO THE EDITOR—

Since my thinking differs from that expressed in your editorial, "Prepare Now for the Technician Gap", Dec. '57, page 93, I am sending my ideas about the training problem.

Your editorial included the following quotation, "The control technician needed for these systems will have to be well-grounded in the fundamental sciences, in mathematics up through calculus, and in the principles of measurement and control." The description you give here is apparently that of an engineer. Your treatment of the subject is a good illustration of the existing tendency to use engineers in the place of technicians. In this way, the problem of a shortage of technicians is shifted to one of a shortage of engineers. The reason for this generally applied, lazy solution to the problem must be that engineers are educated anyway and are available in small amounts for technician work. Technicians are not available. The shortage of engineers, however, is not the real problem.

We can see that this situation is unnecessary if we look at other fields of engineering. For instance, in automobile techniques, engines and cars are assembled, tested, serviced, etc., by technicians without any design knowledge. In radio and television techniques, apparatus is built and repaired by technicians without the slightest idea of even the existence of a differential equation. Nevertheless, these people can be better at trouble-shooting and startup than the man with the formulas. The situation is similar with the maintenance technicians of a complicated automatic telephone system.

It is possible to give people a good

FEEDBACK

working knowledge by simple methods. The literature in the automobile and radio fields shows a wide variety of books at levels ranging from the rather popular to the simple mathematical approach. In control techniques, this type of literature is absolutely lacking.

A couple of years ago I wrote a paper in popular style for my own needs. It helped in training newcomers in process control. To get a solid working knowledge of how a pneumatic controller works and what it does to the process, it took a technician about two to three months, and a person with a bachelor of science degree about three to four weeks. I feel it is possible to do the same for more involved process-control theory at a slightly higher level.

J. E. Valstar
C. F. Braun Co.
Alhambra, Calif.

Wants Heidelberg paper

We are interested in one of the papers from the VDI/VDE Conference, "Modern Theories in Control Engineering and their Usefulness", held in Heidelberg, Germany, Sept. 25-29, 1956. The title of the paper of interest is "Self Optimizing Systems" by E. G. C. Burt, Farnborough, England. The abstract of this paper appears on page 167 of the Dec. '56 issue of your publication.

We would appreciate very much any assistance or information which you might be able to supply on the possibility of obtaining either a copy of this paper on loan, or of obtaining a copy for our permanent use.

Ralph L. Moore
Case Institute of Technology,
Cleveland, Ohio

On page 34 of that same Dec. '56 issue, you will find this statement at the end of a report on the Heidelberg conference: "Complete proceedings of the conference can be obtained by writing VDI/VDE Fachgruppe Regelungstechnik, Prinz Georg Strasse 77/79, Dusseldorf 10, Germany. The price is 75 marks ($18)." Ed.

A job for automatic car retarders

To the Editor—

Would you be so good as to let me know from whom I can get information on rail car track retarders. I have in mind an installation here in Spain in which retarders might be used to decelerate 20-ton coal cars on 1-meter-

You're covered across the board

when you use
General Controls' line of quality automatic controls

In heating, power generation or process regulation, plant engineers everywhere have found that it pays to check first with General Controls. General Controls' comprehensive line ranges from the simplest time switch or thermostat to advanced programmers and recording controllers.

T-231 ROOM THERMOSTATS

For all heating and/or cooling applications. High response to radiant and convected heat. Snap action or mercury switch models. For millivolt, line or low voltages.

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Stainless steel for high sulphur fuels, syrups, juices, acids, alkalis, etc. Pressures to 300 psi. Midget size. Multi-poised – operates in any position.

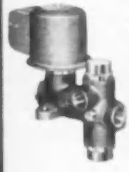
INDUSTRIAL INSTRUMENTS

Pneumatic Recording Controller in cast aluminum case. Assemblies interchangeable. One of General Controls' wide line of pneumatic indicators, recorders and controllers.

PRECISION POTENTIOMETERS

Available to complement automatic controls for automation and instrumentation. Rotary, linear and sector types in miniature sizes. Greater resolution and exceptional stability.

K-123 MAGNETIC VALVE



3 way – for normally open or normally closed directional control and mixer applications – on pneumatic or hydraulic operated devices, machine tools, etc.

B-55G GAS VALVE

Governor Type for "on-off," high-low modulating and air damper control. Slow opening diaphragm. For gas flow to industrial boilers and furnaces.

COMBUSTION CONTROLS

For ultimate operating efficiency of commercial and industrial boilers. Conserves fuel, reduces stack losses, keeps heat in the boiler and provides more efficient heat transfer to boiler water.

HYDRAMOTOR (motor-operated) VALVES

Wide range of types in complete range of pipe sizes and body styles to provide safe, dependable, durable answer to all liquid transfer problems.

COUNTERS

Complete line of counting devices, automatic batch counters and counter actuators from new Production Instrument Division. Electric, manual, stroke, rotary and mercury reset models.

MOTOR-OPERATED GATE VALVE

Typical of precision-built controls designed and produced to rigid military and commercial specs for highly complex systems of modern aircraft and guided missile.

GENERAL CONTROLS

Manufacturers of America's Finest Automatic Controls for Home, Industry and the Military
Glendale, Calif. • Skokie, Ill. • Guelph, Ontario, Canada
Five Plants – 42 factory branch offices serving the United States and Canada

gauge track prior to spotting over unloading hoppers.

The idea developed after reading the excellent article, "Automatic Freightyard Shuffles Cars Quickly Yet Gently", in the Jan. '55 issue of CONTROL ENGINEERING, prepared by Messrs. Berti, Bettison, and Seay [actually written by two CtE editors]. While the application I have in mind in no way requires the exacting control described in the article, I thought you might be able to advise me of the name of a builder of spring-loaded retarders to whom I might write for specific information.

E. W. Schumann
Madrid, Spain

Here are four firms that manufacture railroad car retarders: Union Switch & Signal Div., Westinghouse Air Brake Co., 56 Switch Building, Swissville, Pa.

Brown-Kayro, Knoxville, Tenn.

Fairmont Machinery Co., Fairmont, W. Va.

General Railway Signal Co., Rochester, N. Y.

For information about his operating experience with these retarders you might wish to write to Mr. R. J. Berti, Assistant Electrical Engineer, Union Pacific Railroad Co., 1416 Dodge St., Omaha 2, Neb. Ed.

Review stimulates demand for book . . .

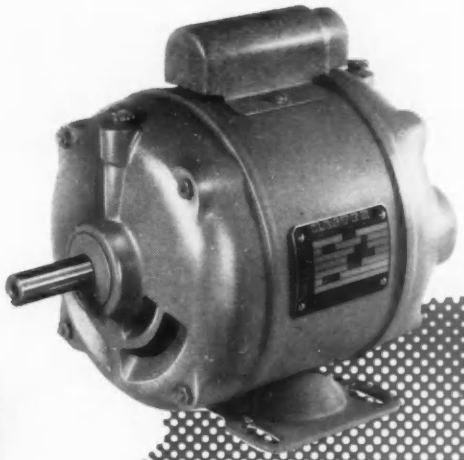
TO THE EDITOR—

At the present time this firm is engaged in some basic research which will utilize a magnetic amplifier technique in the control of the variables of light. Considerable work has already been done in this field by various American manufacturers.

In the Nov. '57 issue of CONTROL ENGINEERING, a new book entitled *Magnetic Amplifiers* by M. A Rozenblat was reviewed by Michel Mamon. As you know, this book was published in Moscow and is available only in Russian. It would be greatly appreciated if you, or any of your readers, would let us know if an English translation is available.

Chester Schuler
Metropolitan Mfg. Co.
Long Island City, N. Y.

. . . but a check of sources yields no English translation. Consultants Bureau and Four Continents Bookstore (both in New York City) and The Library of Congress in Washington know of no translation. Ed.



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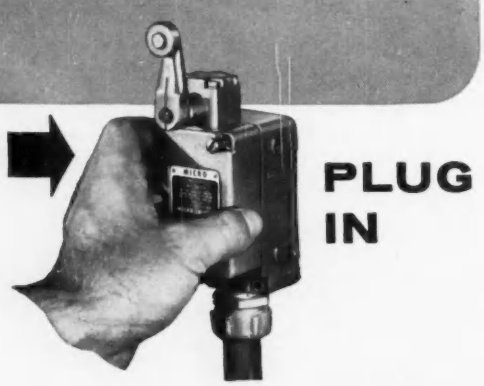


(Send for Bulletin No. 20)

How you can cut "down time" with this "Plug-in Limit" switch

Here's a real timesaver for users of precision limit switches—a revolutionary new precision limit switch that can be replaced IN SECONDS. The MICRO SWITCH "Plug-in Limit" answers a prime requirement for designers of devices for use on high speed automatic production lines. It offers all the features of rugged construction and precise, long-life operation of the industry-proved MICRO SWITCH "LS" Series. Yet the switch enclosure, including all mechanical and electrical parts, is plugged into the terminal block as easily as a radio tube. Dowel pins assure precise positioning.

Switches have uses unlimited

How to get more pushbutton switches on a panel

MICRO SWITCH Series 100 PB Lighted Pushbutton Switches provide an unusually neat, good looking panel. Their compact mounting allows more switches per panel.

Important features include:

Three types of illuminated signal—

(1) one-color buttons, (2) two colors (lighted singly or in combination) and (3) choice of either of two colors—neither of which is visible when button is unlighted.

Large, easily engraved buttons—

Buttons are large enough to allow two lines of clearly legible engraving.

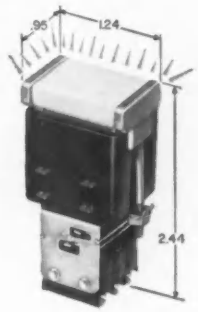
Wide choice of circuitry—

Because separate terminals are provided for each lamp and for each element of the contact structure, these switches permit intermixing of voltages, a-c or d-c current and even combinations of opposing polarities.

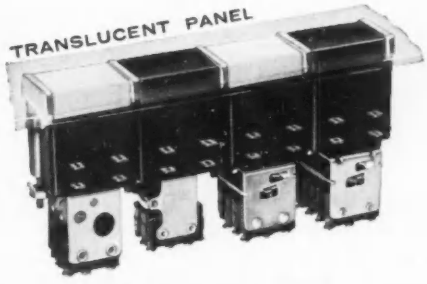
Matching lamp assemblies available—

Matching indicating lamp assemblies are available with the same button and lamp combinations and the same means of mounting as the complete 100 PB switch assembly.

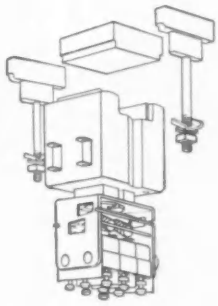
(Send for Data Sheet 143)



Typical switch module on a 3-circuit design.

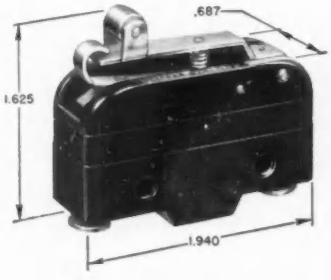


A typical compact assembly of switches in panel slots. Indicates choice of button color and number of circuits.



Exploded view showing switch assembly, button and mounting means.

A roller-lever switch with the stability of pin-plunger switch



A new design in roller-lever actuators is this MICRO SWITCH Type W.

This small, compact roller-lever basic switch is ideal for use of such control mechanisms as radar units, precision machine tools or other devices where precise actuation with little variance in operating points is required.

This Type W switch incorporates a new design in roller lever actuators which gives it an operating stability similar to a pin-plunger switch—low pre-travel, narrow differential travel and close repeatability but also permits exceptionally high overtravel.

The roller is located on top of a double lever. As the roller is depressed, both levers move downward until the switch is actuated. The upper level then proceeds on downward, providing the high overtravel. The limited overtravel given to the snap spring and a low break gives this switch a long, trouble-free mechanical life.

(Send for Data Sheet 127)

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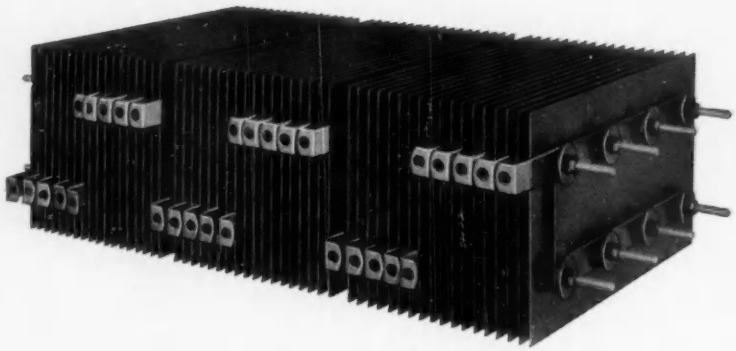
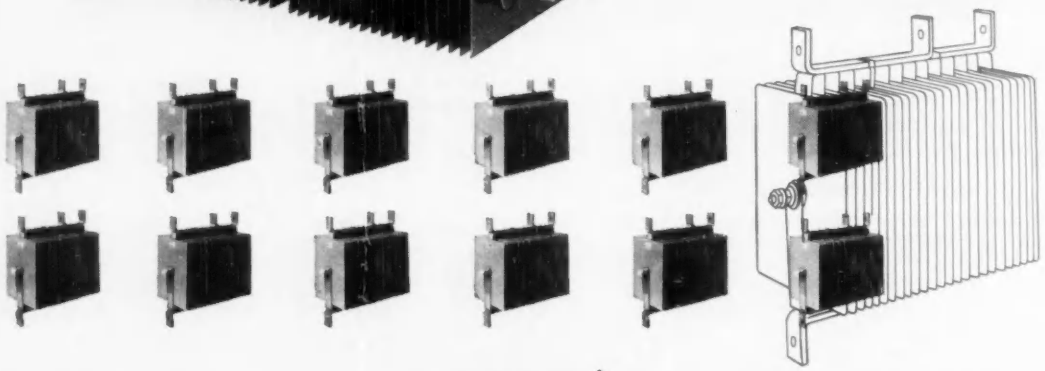
12 full size conventional stacks!





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RRco. Petti-Sel rectifiers do far more than save space. They reduce assembly time, require fewer connections and cost less per ampere. Their dependability has been proved for years in European circuits and the outstanding electrical characteristics are not even approached by other standard cells available today. For further information please write today to Section C-2R.

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ASCHER OPLER

looks for something new

At Dow Chemical Co.'s Pittsburg (Calif.) research laboratories, Ascher Opler occupies a unique niche not immediately obvious from his title of associate scientist. To many Dow scientists, Opler is a high-powered computer specialist. But that only covers part of his role; the problems brought to him stem from widely separated facets of instrumentation.

Opler thrives on this hydra-headed problem diet. He himself has no long-run favorite area of work, only a partiality to the brain-twister at hand. Right now, he's concentrating on computers because Dow has embarked on a program to use analog and digital machines in a variety of ways. And that's uncovered a flock of challenging problems to unravel.

Perhaps the one thread that runs through all of Opler's work is a predilection to use advanced mathematics, most of which he has picked up in his own reading. His formal academic training suffered under the depression. Caught in the maelstrom of the '30's, Opler was buffeted from college to college by economic crises, finally won a degree in chemistry from Wayne University. He started as an instrument engineer in the pharmaceutical industry, switched to food processing during the war, and then turned to chemical instrumentation in Dow's Western Div. Physics Laboratory in 1947.

Applying mathematical analysis techniques to instrument problems turned out to be Opler's strong point. He built up the Physics Laboratory by pioneering new techniques, accumulated several noteworthy firsts: he was among the first to use digital techniques in spectrophotometry; he pioneered multi-component infrared analysis; and he brought a new view to the handling of multicomponent distillation problems.

But a problem he couldn't solve really introduced Opler to computer techniques.

It happened while he was doing work on multipoint infrared analysis. Opler found he could not solve on desk calculators the equations he had laboriously derived. While he searched for a way out, he was inadvertently introduced to digital computing by an IBM salesman who was trying to clinch the sale to Dow of a business-data processing system by adding that the company could also use it to solve engineering problems. The salesman failed to impress Opler with his pitch. But that night after he had gone to bed, the implications of the salesmen's suggestion suddenly struck home. Maybe that data processor could solve the infrared analysis equations! First thing the next morning, Opler was on the phone passing along his equations to the IBM salesmen. The computer solved the problems and Opler was launched in a new direction.

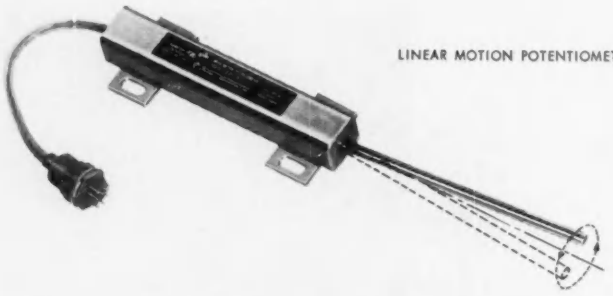
During the last two years, Opler admits, he's gone whole hog for big computers. "They let us do things that you couldn't even think about 10 years ago," he says. One such thing that Opler tried: Solving simultaneous nonlinear partial differential equations describing chemical reactors.

"Since the middle of the 19th century," he says, "we've had to design chemical plants by building hardware and then making changes when it didn't work. There was no effort to analyze these plants, because even if mathematical equations could be devised for the process, you couldn't do anything with the complicated equations. But these big new computers have changed all that. A typical solution requiring 4,000,000 arithmetic operations can now be done in 3 minutes".

In 1952, Opler plunged into something new—topology. Combining his knowledge of chemistry with his new-found fondness for computers, he developed a scheme for programming a computer to search chemical compounds so that a chemist could quickly determine if a new compound had been discovered or locate a compound with specified chemical structural properties. Opler's brilliant work encouraged the Patent Office to proceed with its program to mechanize patent searching.

In 1953, the restless Opler suffered a coronary thrombosis (heart attack). At about the same time, Dow relieved him of the paper work associated with his job as head of the Physics Lab, gave him his present title of associate scientist and permitted him to work on any scientific project that intrigues him.

As to what his next project will be, Opler won't even hazard a guess. But there's one thing he is sure of. It will be something entirely different from what he's working on today. And it will be new.



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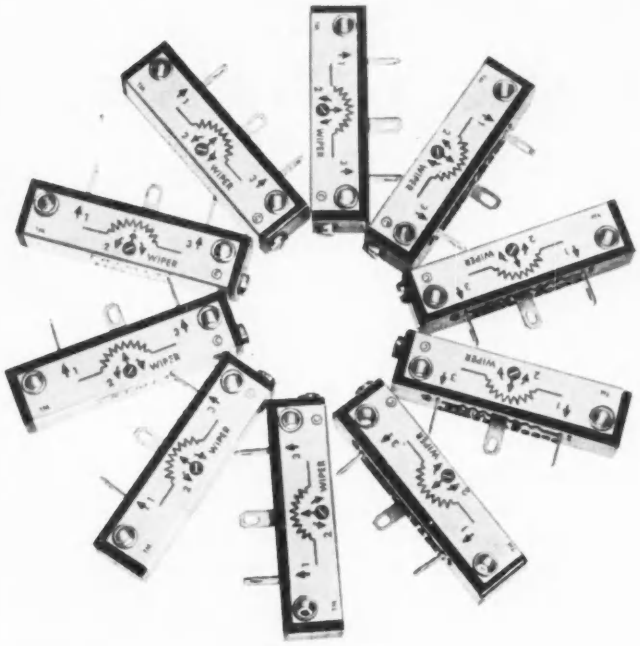

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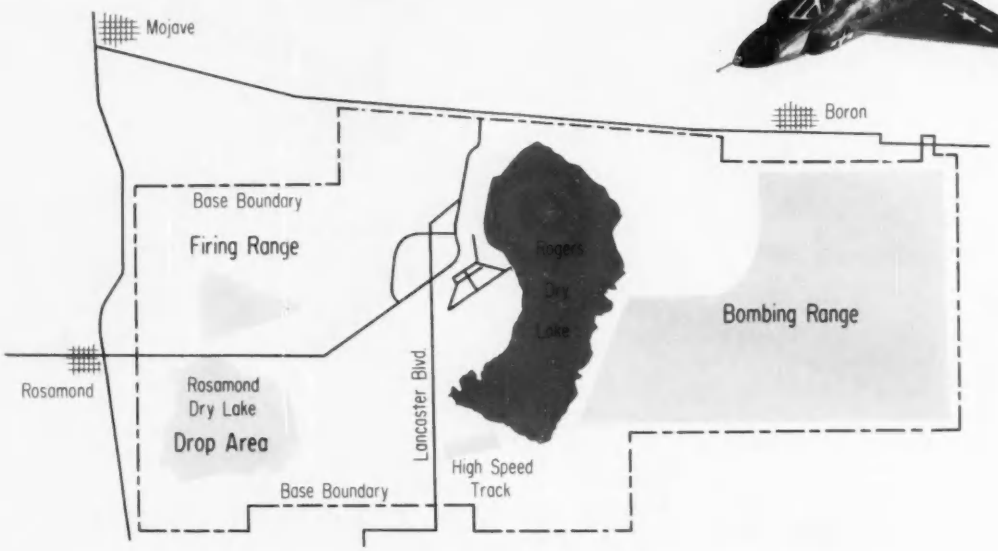
AT EDWARDS AFB

Flight Testing Grows Up



Sputniks and missiles have stolen the spotlight, but manned aircraft is still the first line of U. S. defense. Air Force flight testers are continually improving techniques, adopting modern instrumentation. Recent innovations:

- centralized control room
- extended radar and telemetry ranges
- new data processing setup

The big emphasis on missiles and space satellites has pushed the manned airplane into the back seat. But the Strategic Air Command with its jet bombers is still the U. S.'s first line of defense against attack. And most Air Force strategists will tell you that there's always going to be a place in warfare for the manned airplane. All the publicity about IRBMs and ICBMs has tended to hide the fact that aircraft designs have been changing radically, too. And the changes are forcing equally radical changes in flight-testing techniques.

Last month, a visitor to Edwards Air Force Base—windswept desert proving grounds 15 miles from Mojave, Calif., designated the Air Force Flight Test Center of the Air Research & Development Command—could see or hear about still four more big instrument projects in the works:

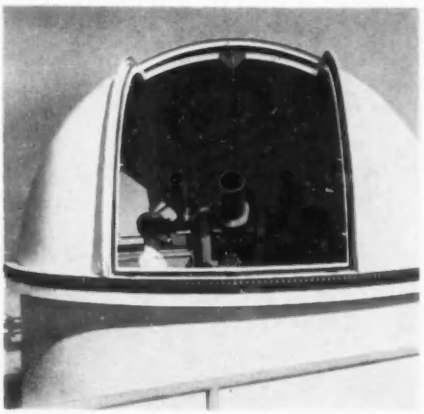
▶ New Askania position range is completed. Its nine accurately located Askania phototheodolites (precision cameras that take photographs at a rate of 3 per second) can pinpoint an airplane's location within 5 ft at 50,000 yards.

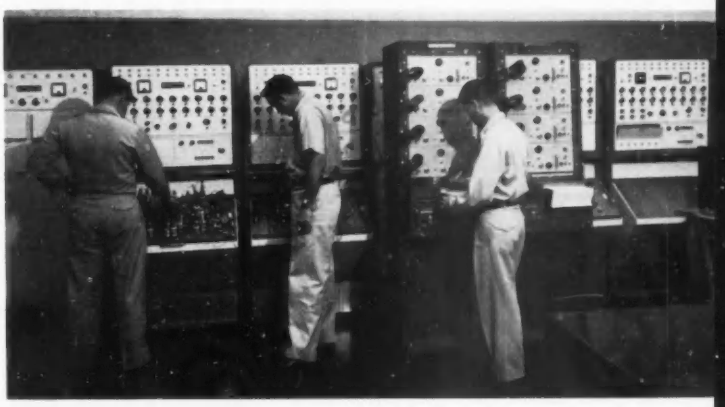
▶ Plans have been completed for a new radar tracking range that will extend the present air test strip from its present 70-mile length to over 400 miles, pushing the terminus deep into the State of Nevada. To do this, up-range stations will be built at two Nevada towns, Beatty and Ely. And a new radar data system will tie the Nevada stations to a soon-to-be-built central control room.

▶ The telemetry range will be extended along with the new hi-range radar system. Manned telemetering stations will be built at Beatty and Ely and unmanned remote stations will be located at strategic points in-between to complete the telemetering chain. When completed, telemetry information will also be relayed to the central control room.

▶ A new data processing center is under construction to handle mushrooming volumes of test information.

New instrumentation gives California's desert a science fiction look. Maze of antennas on roof makes identification of telemetry building (right) easy. New Askania phototheodolite range has dotted landscape with spherical-shaped slave stations (below). Inside the instrumentation laboratory, engineers simulate the flight-test envelope on a GEDA analog computer (below, right) equipped with four linear and three nonlinear units.





Named "Project Datum", the data processing facility will use an IBM 704 computer instead of the smaller Datatron which has been solving flight-test problems since 1955. The switch to the 704 is the first step towards proposed wide-spread reliance on magnetic tape for handling data.

• **How flight testing changed**—These instrumentation additions mirror a steady growth in the complexity of flight-testing techniques. When aircraft were first tested in the Mojave desert in 1937, when the base was the Muroc Army Air Base), the test pilot was the most important instrument. He took the plane up, put it through its paces, and then, after landing, reported how the aircraft performed, to the engineers who were examining it. A key "measurement" was the way the test pilot felt the ship handled.

When increasing aircraft requirements—particularly higher speeds and altitudes—obsoleted seat-of-pants testing at the end of World War II—one of the first innovations was the installation of special test instruments in the cockpit to supply the pilot with quantitative information on the test, a practice still followed today on many test flights. But as the piloting operation became still more complicated, the pilot found less time to read instruments and record data. Flight-test engineers found they had to rely on instruments for data.

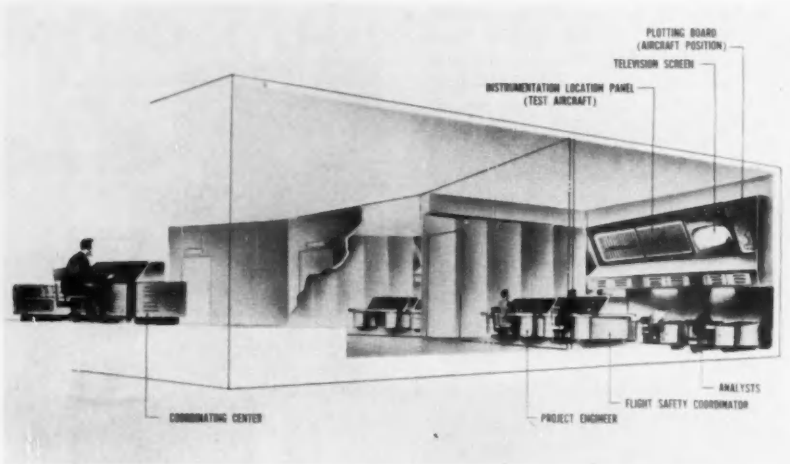
Testers devised the photo panel, produced by continually photographing the flight instruments with a movie camera; they developed special lightweight, rugged, airborne oscillograph recorders; and they put to use some of the newly learned techniques of radar and telemetry.

Today the Air Force's investment in instrumentation at Edwards AFB runs over $30 million. The four new projects will add an additional $10 million to that. This instrumentation is the responsibility of the Technical Facilities Div., part of Edward's Directorate of Flight Test and headed up by Charles Oliver.

• **Tracking**—On the range the Askania camera is the workhorse for obtaining accurate position data. Operated manually by two trackers, the Askanias are talked onto the target by radar—an operation which was greatly simplified last year by the installation of PARTAC (Precision Askania Range Target Acquisition and Control). In the PARTAC system, radar signals are fed directly to a special-purpose computer where they are converted to azimuth (both horizontal and vertical) signals that are transmitted to the Askania station, showing up as lights on the theodolite eyepieces; camera operators pan towards the lights to "get on" the target.

Although Askania photos supply highly accurate position data, flight testers are not completely satisfied with them. The reasons: the three days to a week it takes to convert Askania films to usable data. One answer, according to Edwards radar specialist M. E. Phillips, is to digitize radar signals and put them directly on magnetic tape ready to feed into the IBM 704 computer. He feels this could cut position data processing time to four hours.

• **Precision digitizing radar**—The first system to do this is already being built for use at Edwards. With it, digital azimuth, elevation, and slant range information from instrument radars will be recorded both on magnetic tape and on visual data panels.



New centralized control room will permit project engineers to have instantaneous access to telemetry data and position information.

FLIGHT TESTING . . .

STORY STARTS ON PAGE 22

Antenna position, as the antenna tracks a test vehicle, will be obtained from the azimuth and elevation shafts by connecting the transducers—two optical analog-digital shaft position indicators, each with a single glass code photo plate engraved with 16 binary digits—directly to the antenna shafts. The tape will also carry the AFFTC central timing signal generated by the PARSET equipment.

But until such gear is perfected, radar's main jobs remain 1) talking the Askania cameras on targets, 2) supplying backup photographic information with a radar phototheodolite, and 3) serving as primary guidance for pilots on bomb-range tests.

• **Telemetry** – Edwards' present ground telemetry station, blossoming under Paul J. Sehnert's supervision, will serve as a model for the manned stations soon to be built in Nevada. It can handle 90 channels, ten times a second, with its two Bendix fm/fm stations (one mounted in a van to provide mobility when reception is bad), two Ascop PWM fm stations, a Teledynamics miniaturized fm/fm station, and a EMR fm/fm ground station. There is a variety of data handling equipment, reflecting the fact that for many variables in flight testing all that is required is a time history.

One innovation that Sehnert's group is studying is how to use television to aid flight testing. Typical applications under study include a method to check instruments in the cockpit to determine if they are reading the same as those on the ground; and to check landing gear in the up and down position.

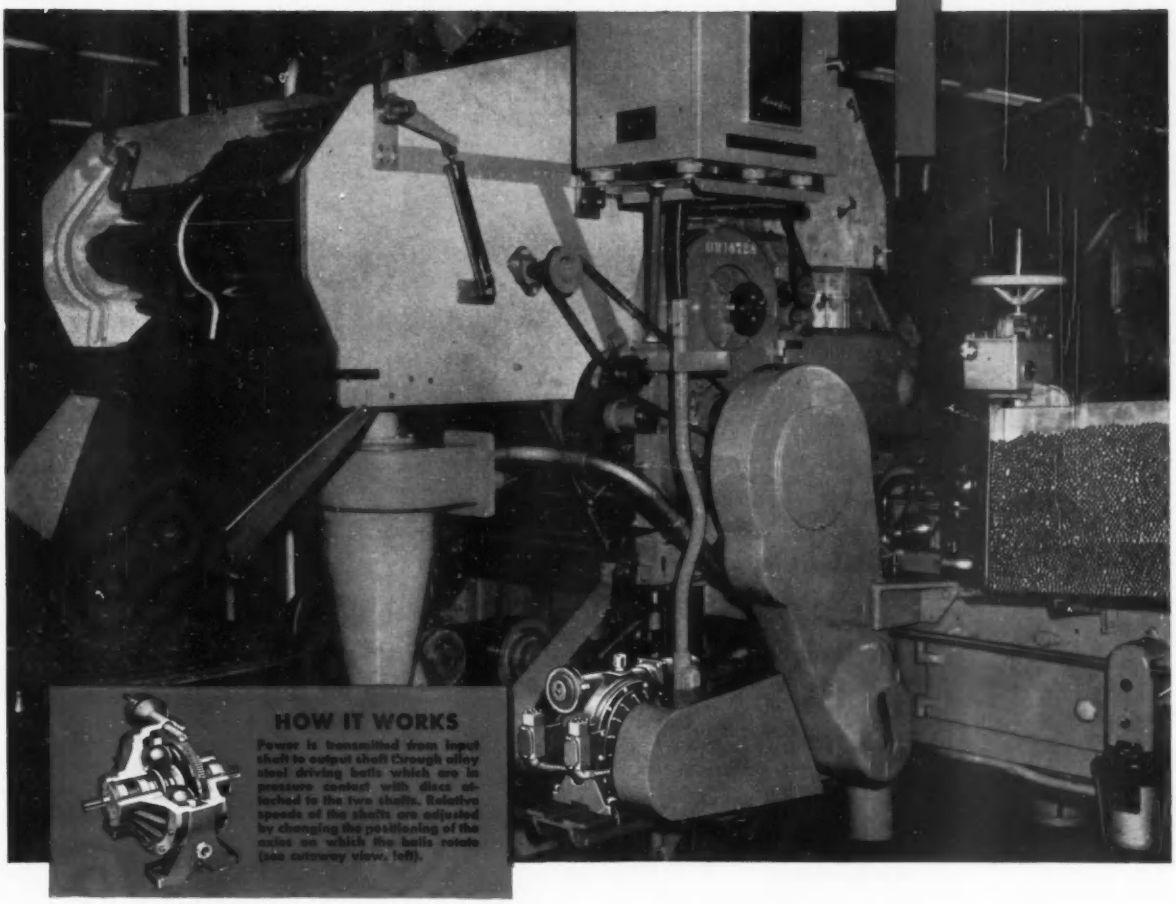
• **Instruments Branch**—In a temperature and humidity-controlled building, Edwards' instrument technicians and engineers perform a variety of operations aimed at getting proper instruments in project engineers' hands. Because transducers used in aircraft testing are subjected to extreme environmental conditions, each device is environment-tested in the instruments lab before it is installed in a plane. Because airborne telemetry equipment is used over and over again, it often has to be repaired, and recalibrated—a problem missile testers rarely have.

For tests that require specially developed devices, the Instrument Branch digs into development know-how to design and build new transducers and measuring equipment. One such accomplishment is a special-purpose device for measuring side-slip and angle of attack; Edwards instrument men call it the YAPS (Yew and Pitch Indicator) head.

• **Central control**—When the new hi-range radar system and the new telemetry chain go into operation, data from both will be relayed to Edwards' first centralized control room. Up to now it hasn't been necessary to use centralized control in aircraft flight testing, but increasing pressure to

AccuRay electronic brain gets muscle power from Cleveland Speed Variator

The electronic control mechanism of this cigarette machine, known as the AccuRay cigarette gage controller, built by Industrial Nucleonics Corp., Columbus, Ohio, employs Cleveland Speed Variator size 4K4, driven at 1200 rpm input.



HOW IT WORKS

Power is transmitted from input shaft to output shaft through alloy steel driving balls which are in pressure contact with discs attached to the two shafts. Relative speeds of the shafts are adjusted by changing the positioning of the axles on which the balls rotate (see cutaway view, left).

NATIONALLY famous for checking and controlling the making of Chesterfield cigarettes, AccuRay depends on a Cleveland Speed Variator for the delicate job of adjusting the tobacco feed rate in response to impulses from the gaging mechanism.

Being infinitely variable, the Cleveland Speed Variator gives stepless speeds over a full 9:1 range — from ⅓ to 3 times input speed. Output speed on this application is adjusted automatically by a regulating motor mounted on the Variator — but could be regulated manually or by remote controls of other types.

Available in eighteen standard types and sizes, the Cleveland Speed Variator offers these major advantages: 1. An extremely compact unit with input and output shafts in line and rotating in the same direction; 2. Almost any input speed up to 1800 rpm can be used — either clockwise or counterclockwise rotation; 3. Rated for constant horsepower output over a 9:1 range, or for constant output torque with a 6:1 range; 4. Infinitely variable over the entire speed range; 5. Rapid response to speed change, precise adjustment, and accurate maintenance of speed settings; 6. Long life and minimum maintenance due to absence of belts or complicated linkages; 7. Ample bearing support for overhung pulleys on either input or output shafts.

Write for Bulletin K-200 for detailed description with photographs, sectional drawings, rating tables and specifications.

THE CLEVELAND WORM AND GEAR COMPANY

Speed Variator Division, 3260 East 80th Street, Cleveland 4, Ohio

Sales Representatives in all major industrial markets • In Canada—Peacock Brothers Limited

WHAT'S NEW

...changes in data processing equipment mark the growth of flight-testing techniques . . .

make more real-time decisions based on test data have forced the move. In the new control room, project engineers responsible for the test will have instantaneous access to telemetry data for "quick-look" while automatic plotters locate vehicle position continually through the test.

This arrangement emphasizes one of the characteristics of the work at Edwards. Most of the activity is aimed at recording flight parameters. The Mojave desert testers are usually less interested in monitoring equipment performance than are engineers during a missile shoot.

Project Datum

Another way to measure the growth of flight testing techniques is to look at the changes in data processing equipment. When Edwards started testing aircraft the slide rule was the tool used to reduce data. As the volume and complexity increased, AFFTC went first to desk calculators, then to punch-card calculators, to an ElectroData Datatron in 1955, and to an IBM 704, about to be installed.

Project Datum is the name that's been applied to the centralized data processing program that was originated for Edwards AFB by Electronic Engineering Co. of California. The system also has to handle data from Edwards' Rocket Engine Test Facility and High Speed Track Tests. There are two main sections: a "Quick-Look" and a digital data reduction group.

The Quick-Look group is of major importance in filtering flight test data. TFD Assistant Chief J. J. Dover estimates that only 1 percent of the recorded data has to be processed by the computer. And it's in the Quick-Look stage that the project engineer identifies that essential 1 percent.

From an equipment standpoint, the Quick-Look room closely resembles a ground telemetry station. Data recorded on magnetic tape is first played back at regular speed and the beginning and end of information for digital processing is noted. A specially designed Search & Control Unit is then used to 1) locate the specific data start-and-stop time on the tape, 2) take timing information as recorded on the tape and translate it for proper recording on the chart recorders, and 3) automatically con-

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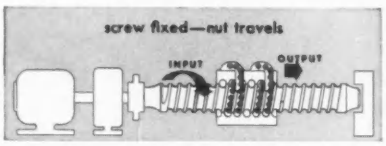
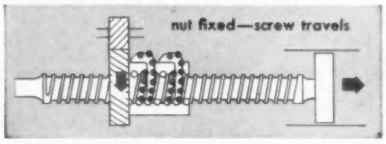
WORLD'S SMALLEST ball/bearing SCREW SOLVES CRITICAL MINIATURE POSITIONING/CONTROL PROBLEMS



NUT TRAVELS: When rotary motion is applied to the screw, the b/b nut glides along the axis of the screw on rolling steel balls, converting rotary force and motion to linear force and motion with 4/5 less torque than acme screws.



SCREW TRAVELS: When rotary motion is applied to the b/b nut, the screw glides along its longitudinal axis on rolling steel balls, converting rotary force and motion to linear force and motion with unprecedented efficiency.

An unprecedented achievement in minimum size and weight—maximum efficiency, dependability and service life for ultra-precise controls.

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WHAT'S NEW

trol operation of the magnetic tape playback machine and starting and stopping of recorders.

Once the time at which desired data occurs is programmed into the system, the Search & Control unit plays the tape at a speed of 120 in. per sec instead of the usual playback speed of 15 in. per sec.

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▶ To digitize the selected portions of data

▶ to edit and sort the data points by selecting desired channels and sampling rates

▶ to perform data corrections for system errors and transducer nonlinearities and to change data scale factors

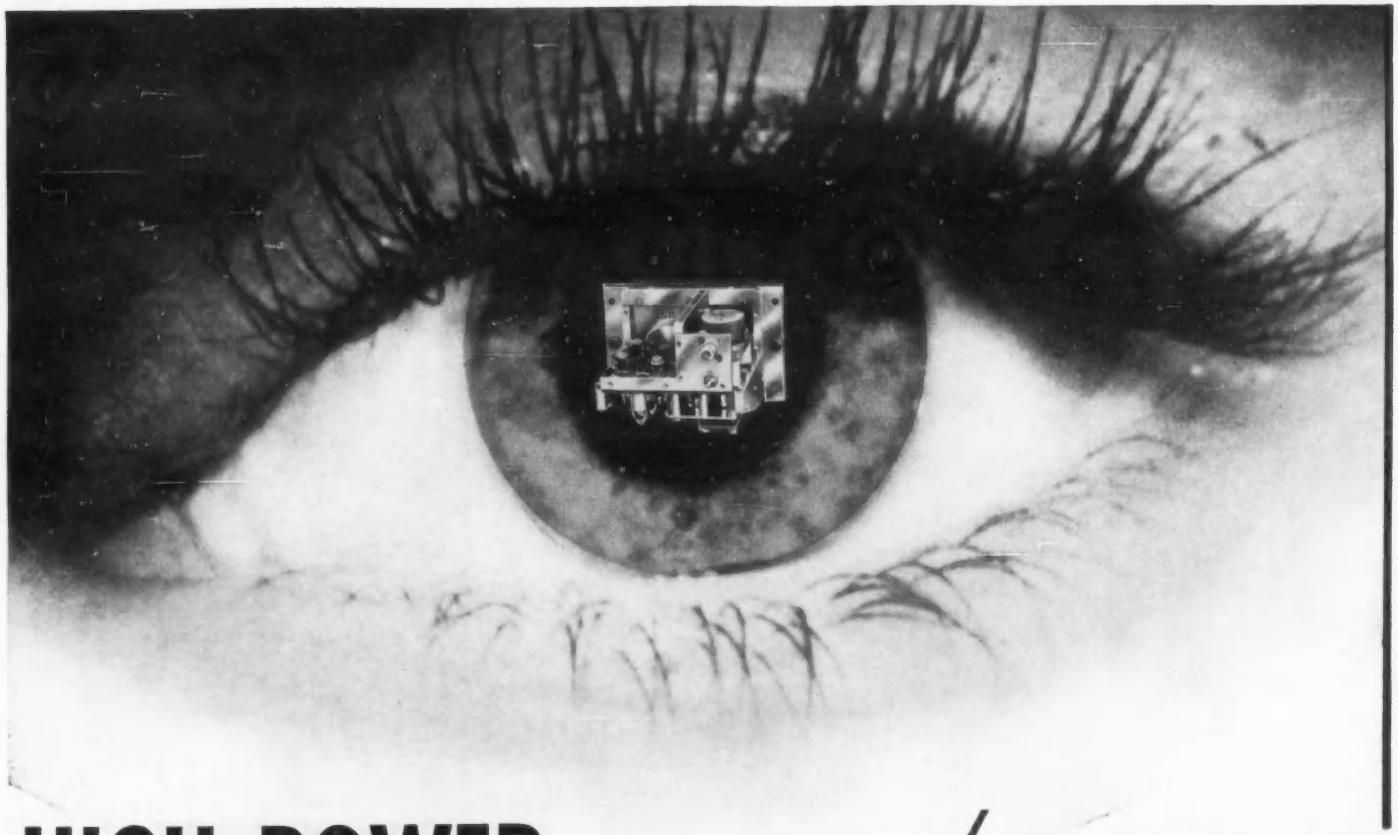
▶ to provide linearization facilities for a limited number of data channels

▶ to convert the data to a standard usable form so that it can be presented in tabular form, point-plotted form, or entered into a general-purpose computer for further calculation

• **Simulation plays a role** — Since 1955, flight-test engineers have been using an analog computer to simulate certain aspects of flight test, interpreting the results to find critical spots on potential tests. First simulations were forced by the inertia coupling problem in supersonic aircraft. During high-speed roll, the testers discovered that wild oscillations could be built up by these couplings—a condition that the pilot is unable to control and that can tear the airplane apart. Using a simulator they can determine before the flight test how far the pilot can go without developing the destructive oscillations.

• **For the future**—The accent on missiles hasn't slowed the development of flight-test techniques.

The prospect is for even more growth in the future. Typical areas under study: development of digital devices for telemetry application, and development of high-speed automatic data reduction techniques. And coming closer to actuality is an optimum operation in which data from the test will be transmitted directly to computing facilities that supply the project engineer with finished data on a real-time basis so that the test with all its data is completed when the plane lands. **—Lewis H. Young**



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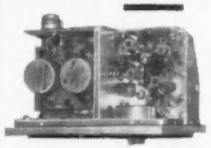
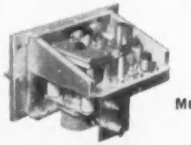


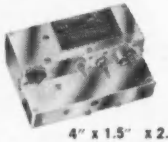
Model 1462

6" x 4¼" x 3¾" 50 to 80 Watts



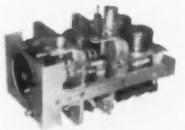
Model 1463

5 9/32" x 3 1/16" x 4" 15 to 30 Watts



Model 1472

4" x 1.5" x 2.7" 2 Watts



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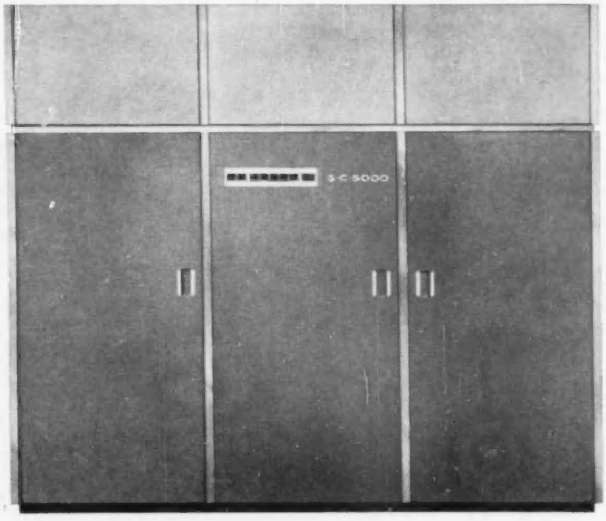

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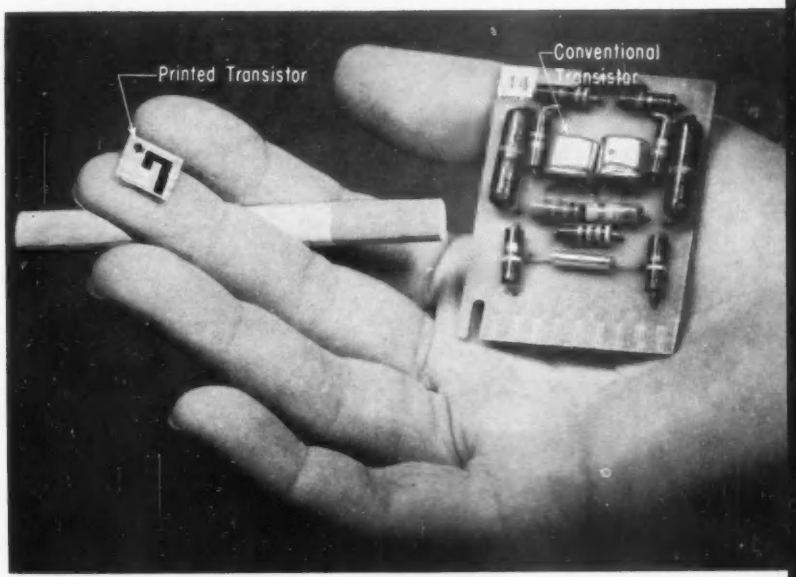
Army Develops Printed Transistors



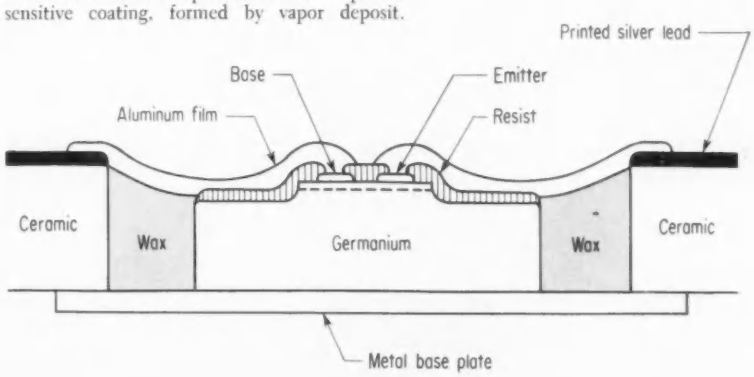
Army scientists show a revolutionary technique for printing transistor systems; still in the research stage, it portends major space savings, possible production advantages.

WASHINGTON—Printed circuitry techniques have helped electronics make deep inroads in control equipment. They have opened the door to easier maintenance—a trouble-shooter can replace a group of components just by replacing a card—and to tremendous space savings. Now scientists, with an eye to missile and computer applications, have scored a new advance: at the Army's Diamond Ordnance Fuze Laboratory they've developed a method of printing transistors, and transistor systems like a flip-flop (see photo).

The new process cuts the size of the unit to only 1/20 in. wide and 1/100 in. high; 200 of these printed circuits can fit into 1 cu in. Inventors Dr. J. W. Lathrop and James R. Nall predict that eventually they will be able to put 1,000 transistor units into a cubic inch. For missile systems, the printed transistor circuit will have one additional advantage: increased resistance to shock and vibration.

Even more significant may be improvements in production introduced by the new process. Manufacturers will tell you that making a transistor is still a tricky procedure. It requires tedious and exacting work, usually involving the use of microscopes to locate the filament wires. And results are never sure. Suppliers still end up with a relatively high number of rejected units.

Base and emitter are positioned with a photosensitive coating, formed by vapor deposit.



The new development is the result of a two-phase research program. It started with the development of photolithographic fabrication techniques for making transistors. The second step was to make these transistors an integral part of the printed circuit.

DOFL's process begins with a tiny wafer of germanium. A photo-sensitive coating provides precise positioning needed for the pinpoint electrodes, then formed by vapor deposit.

Probably the most important part of the process is printing the leads by evaporation and deposition of aluminum. To do this, a coat of Resist is first placed over the transistor, exposing only the areas directly over the emitter and base contacts. Sometimes an additional layer of gold is electrolytically deposited in these areas to assure good contact.

Next the transistor is soldered to a thin circular base plate and inserted into a hole in a ceramic printed board like a stopper in a bottle. An insulating cement fastens the transistor to the board. With crude masking in place, it is possible to vacuum-deposit aluminum leads which connect the printed wiring on the ceramic board with the contacts on the pedestal.

These leads have a conductivity equivalent to a wire 0.0006 in. in diameter. The photo Resist acts not only to insulate the deposited leads from the germanium surface but also to protect the surface from contamination until the entire circuit or combi-

WHAT'S NEW

nation of circuits can be hermetically sealed.

The application of Resist apparently does not affect the transistor and no changes of characteristics have been observed on units coated with the material over a period of days.

Lathrop and Nall are quick to emphasize that the new development is still in the research stage. So far they've only used diffused-base p-n-p germanium transistors at very low power. And they've been shooting for high-frequency operation at present (f_α equals 15 mc).

Although performance still doesn't match commercial, conventionally-made transistors, the inventors expect improved versions to be on a par. They also anticipate that when (and if) production is started, the printed transistor will compete favorably with tubes cost-wise. The new process looks ideally suited to rapid mass-production of transistor systems at low cost.

Semiconductor Progress: The Controlled Rectifier Nears Production

A controlled rectifier—a semiconductor device comprising more than two rectifying junctions—has been developed by the General Electric Co.'s Rectifier Engineering Laboratories. GE engineers have built prototype models able to handle enough controlled power to satisfy many military and industrial applications. Samples should be available for equipment designers in a few months. And quantity production is scheduled to start this fall.

First word of this development came from H. Brainard Fancher, general manager of GE's Semiconductor Products Dept., speaking before the Cleveland Society of Security Analysts. Fancher said, "Our engineers have built some prototype samples using silicon to perform the same function as a gas thyratron."

Although scientists have been saying for several years that it could be done, this announcement apparently is the first indication of a concrete development. By providing control engineers with a means to vary the amount of direct current coming out of a rectifier, the new device can replace gas thyratrons (which do the same thing electronically and complicated mechanical means.

Fancher pointed out that thyratrons are too big and too temperature-limited for many applications. In addition, there are the same life limita-

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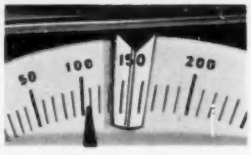

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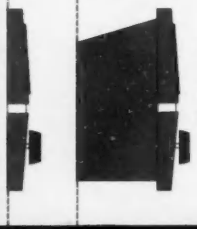

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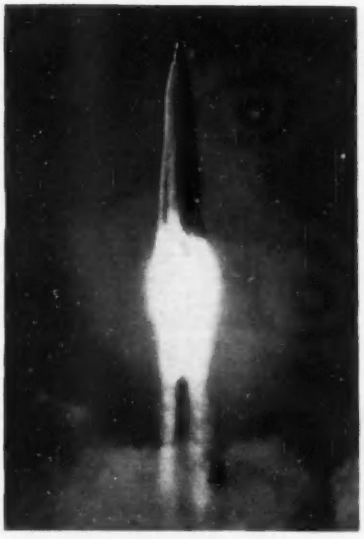
WHAT'S NEW

tions as other vacuum tubes. The controlled rectifier, or semiconductor thyratron, he said, is about 1/100 the size of equivalent gas thyratrons, has virtually unlimited life, and can operate at temperatures up to 150 deg C.

Probably the biggest use of these new devices at first, according to Fancher, will be in military equipment and industrial machinery. "They will find wide use replacing 'latching-type' relays in circuits for switching power," he predicted.

"The controlled rectifiers we have seen so far," said Fancher, "can switch and control a load of 200 volts and 5 amperes or 1.5 kilowatts of power with only 15 milliwatts injection at the control lead. This is a control ratio of 100,000 to one."

Specific applications for the new device seen by Fancher include replacing power transistors in missile-control systems (where the transistors are used as switches to convert low-voltage dc from a battery to either high-voltage ac or dc). Another potential application is in automatic machinery, where the speed of motors is controlled by computers, punch cards, or magnetic tape. This motor control, Fancher pointed out, must be accurate, fast, and dependable.



Atlas ICBM gave Convair missilemen their best Christmas gift when it successfully completed its first flight test the week before the holiday. The test, over a limited range of about 500 miles (Atlas's ultimate range is 5,000 miles) was followed by a second success in mid-January.

EUROPEAN REPORT

Theorists Clash Over Labor's Future Role

NAMUR, BELGIUM—

Where will the working man fit, in an economy dominated by automatic production? European experts gathering at the annual general meeting of the International Cybernetic Association in Namur tried to answer that question. And although no finite answers were forthcoming, the meeting served as a sounding board for both labor and management-oriented views. Both sides heard some unsettling statements.

Brussels Professor Georges Boulanger, the association's president, started the fur flying in his keynote speech. His opening gambit: "Human progress and improved standards of living cannot continue unless 'automation' destroys between 10 and 20 million human jobs by 1975."

Said Boulanger, "We are verging on a serious and permanent labor shortage, affecting the U. S. as well as Europe. The shortage is caused by living standards advancing faster than production, leaving the world without the reserves of unemployed resources we have been familiar with in recent centuries."

The Brussels professor offered some figures to back up his contention. "In the U. S. in 1940," he said, "there were 57 million workers competing for only 47 million jobs. By 1955, the situation was almost balanced: 60 million jobs and a million or so more workers. But by 1975, it appears there will be a need for 84 million workers just to maintain existing living standards for the increasing population (105 million if the present improvement in living standards is to be continued); to do this job there will be only 82 million workers available."

Then Boulanger set labor leaders on the edges of their chairs by warning that it was no use to give anodynes to workers and labor unions, no use to promise them "the same job in the same place" or to offer guarantees against redundancy. He said, "The furtherance of 'automation' is the crying problem of our age. Workers should not be bemoaning the menace of automation what will hurt them more, as consumers, is the sapping of automation efforts by loose talk and soporifics ladled out to the labor movement by short-viewed, vote-catching governments."

• **Attacking the high cost**—The audience had barely recovered from Boulanger's sharp-worded presentation when Maurice Lachin, chief of the Full Employment Agency of the French National Organization Committee, rose to attack the high cost of automatic production, higher he declared, than the yield. Said he, "A machine costing a billion French francs would fall short of replacing 200 workers economically. Few companies can begin by getting big automatic machines working at top efficiency. And there aren't too many firms in Europe able to bet a billion francs on expansion capacity. Getting increased business is the only way to make such equipment economical."

Labor's fears can be assuaged, Lachin added, by a look at what has happened in the past. Labor has grown richer as the use of automatic machinery has increased. Besides, said the French official, man-displacement claims made by manufacturers are almost always grossly exaggerated.

• **Shift to services**—Fred Polak of the Netherlands School of Economics sees automation sending a higher proportion of manpower into services. The proportion in productive phases of industry—already falling sharply in the U. S. and elsewhere—may fall still more rapidly. Nothing, he predicted, will be immune from automatic production techniques as the world moves "from the pushbutton age to the age of self-pushing buttons".

Max Gottschalk, Solvay Sociological Institute, provoked a floor argument as he blamed automatic machinery for the firing of workers in Coventry, England. Gottschalk said European workers could reasonably claim a four-day work week (CtE, Oct. '57, p. 59), longer holidays with pay, and freedom from monotony in their work. Lachin interrupted Gottschalk to argue that the firings at Coventry had been caused by a nose-dive of sales of British automobiles, had nothing to do with the problems of automatic machinery. Gottschalk concluded his presentation by predicting the biggest labor difficulty with automatic machinery would be redistributing work inside the factory.

Another area of interest to the cybernetics meeting was the difference in attitudes between workers and

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ST363	60	15 min.	5(10Ω)	15 @ 60V
ST333	30	15 min.	3(6Ω)	15 @ 30V
Rise time: .5 μsec. max. Storage + Fall time: .6 μsec. max.				Ib = 50ma Ic = 500ma
500 ma TYPES				
ST263	60	20-80	5(10Ω)	15 @ 60V
ST233	30	20-80	3(6Ω)	15 @ 30V
200 ma TYPES				
2N498	100	12-36	8(40Ω)	100 @ 100V
ST264	60	20-80	4(20Ω)	3 @ 60V
2N497	60	12-36	8(40Ω)	100 @ 60V
ST234	30	20-80	4(20Ω)	3 @ 30V
50 ma TYPES				
ST265	60	20-80	2(40Ω)	15 @ 60V
ST235	30	20-80	2(40Ω)	15 @ 60V

Featuring:

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WHAT'S NEW

Boulanger: sees a labor shortage.

management over automatic machinery. Miss Joan Woodward, head of the Management Research Unit at Southeast Essex Technical College (England), reported the results of a recent investigation conducted by her group.

She said there was a growing confidence by management in automated industries that the man who delegates authority feels that his subordinates will make the same kind of decisions as he himself would make. Other conclusions: 1) automation expedites business decisions by bringing all the facts before the people who had to make these decisions; and 2) the new generation of management would be closer to the technicians because business leaders would be unable to make decisions unless they knew what they were talking about (a statement that inspired one speaker to comment that this in itself would be an industrial revolution).

• **Labor unions' view**—A key labor speaker was Walter Schevenels, general secretary of the European Office of the International Confederation of Free Trade Unions. Schevenels bore the brunt of presenting labor's attitude on automation. He said that labor unions were not hostile to automation itself; but they could not help seeing possible dangers and they insisted—and would insist by force if necessary—that governments take measures to protect the working man. He continued, "It is a question of matching the tempo of production growth with consumption growth. In the final analysis, it is only by seeing that people have jobs and get wages that you can create the demand to make automatic production necessary."

Schevenels agreed that the newly-established six-nation European common-market—which started operation officially on Jan. 1, 1958—would

give Europe a chance to use automatic production techniques in line with the U. S. and Soviet Union.

—A. P. L. Gordon

Electronic Reader to Process Drug Sales Records

First British installation of an electronic character reader is being readied. Developed and announced last summer by the Solartron Electronic Group, the device (called ERA for Electronic Reading Automation) can scan 300 characters per second, converting the printed letters into punched tape or magnetic tape. The first buyer: Boot's Pure Drug Co.

Boot's will use ERA in a new cash-control system devised by its Organization & Methods Dept. Installed at Boot's Nottingham headquarters, the device will read the printed sales records produced on rolls by the cash registers in each of the firm's 1,350 branches scattered over England. After the register rolls have been received at Nottingham, the totals will be digitized straight from the printed figures by the ERA machine, then fed, without any storage, into a special electronic sterling accumulator developed by Elliott Bros., Ltd.

Special printed coding on the tally rolls will permit discount totals to be determined. And Boot's will, at the same time, be able to measure sales of its own manufactured items against sales of other proprietary brands that they handle.

Total cost of the new installation is about $125,000, with the ERA machine representing more than half of this, or $70,000. It is scheduled to be operating by January 1959.

British Builder Opens Control R&D Lab

Constructors John Brown, Ltd. has opened a new research and development laboratory to extend the firm's activities in the chemical engineering, automatic control, and nuclear engineering fields.

The new laboratory will undertake a variety of sponsored development work in these fields for both government and industrial organizations, as well as conduct projects for CJB's own engineering and construction divisions. The facility will be equipped with pilot-plant buildings.

WHAT'S NEW

Military Electronics

Maintenance stacks up as a major problem; repair costs explode as volume increases. Armed services look for help.

Electronics has done more to revolutionize military tactics and equipment than all the famous tacticians. But it has also given the military a king-sized headache. The big problem: how to maintain the mushrooming volume of military electronic equipment, gear that ranges from a transistorized walkie-talkie to the guts of an ICBM.

Military brass reach for the aspirin when they note facts like these:

- U. S. repair bill for military electronics is close to $20 million per day.
- Cost of repairing military equipment during its life can run as high as 10 times its original cost.
- By the time electronic equipment arrives at a stage where its performance, reliability, and maintainability are optimum, it's obsolete.

To see what could be done to ease such harassment, representatives of the Defense Dept. and industry met at the University of Southern California in a session sponsored by the Electronic Industries Association. After two days, the experts could see no easy solution in sight. They agreed the only answer was to keep the maintenance problem constantly in mind.

The meeting coincided with the publishing, by EIA, of a booklet entitled "Suggestions for Improving the Maintainability of Military Electronic Equipment for the Designer, Installer, User and Maintainer". First order of business was a discussion of this booklet. Typical suggestions:

- Select components that qualify under accepted standards, or with known capabilities wherever possible.
- Apply suitable safety factors to compensate for any variable conditions which may be encountered.
- Arrange components so that they are easily accessible for testing and maintenance operations.
- Provide adequate ventilation; where necessary add blowers to keep components within safe ratings.
- Compensate for any known limitations in a particular component in the end-equipment design.

Although the various suggestions included in EIA's booklet had unanimous approval, there was also unanimous agreement that it isn't

first of the new

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UNIT PREAMPLIFIERS

with Integral Power Supplies

These new Sanborn Unit Preamplifiers—designed to drive optical recording systems, tape recorders, wide band oscilloscopes, panel meters and other devices—offer you an outstanding combination of performance characteristics, operating versatility and ease, flexibility through interchangeable design, and compactness in either single unit or four-unit rack module packaging. The 1100 Carrier and 1800A True Differential DC types are versatile enough to cover the vast majority of input signal requirements, with practically any type of transducer. (For use with high speed optical galvanometers at frequencies above 500 cps, requiring larger current swings, a transistor output amplifier is built into the 450-1800A and available as optional equipment on other 450's.) Later "450" Unit Preamplifiers will include Servo (demodulator) Monitor, DC Coupling, Logarithmic, Low Level and Dual-Channel DC types. As shown, any "450" can be installed or quickly interchanged in any bay of the four-Preamp module, or in a portable case.

Supplementing the basic specifications, the 450-1100 is a carrier amplifier-demodulator with zero suppression, which provides excitation for and accepts the outputs of various resistance bridge, variable reluctance, differential transformer and other types of transducers. The 450-1800A is a low-noise, low drift, wide band-width, high gain true differential DC amplifier, with front panel controls for smooth gain, position, and internal 2 mv calibration signal. For further data or application information on these new self-contained Unit Preamplifiers, contact your Sanborn Industrial Engineering Representative or write the Industrial Division of Sanborn Company.

SANBORN COMPANY

175 Wyman St., Waltham 54, Mass.

SPECIFICATION SUMMARY

MODEL 450-1800A TRUE DIFFERENTIAL DC PREAMPLIFIER

Input — Impedance: 200K differentially between terminals (balanced) or 100K each input lead to gnd. (single-ended)
Common mode rejection: at DC, 100 db; to 60 cps, 94 db; 400 cps, 80 db.
Equiv. input drift: ±2 uv for 24 hours
Equiv. input noise: 5 uv peak to peak (0-10 cps), 20 uv (0-1000 cps), 50 uv (0-30 kc)

Output — Low Power Circuit:
Output appears between two cathodes as true push pull signal.
Common mode level of cathodes ±.2 volts with respect to ground.
Output capability: ±3 volts into 5000 ohms
±10 volts open circuit
Zero position control *not* active for this output
Freq. response; 3 db down at 30 kc
Linearity: 0.1%
High Power Circuit:
Output appears between two emitters as true push pull signal.
Common mode level of emitters ±2.5 volts with respect to ground.
Preferred load: 50 ohms
Output: ±2.5 volts, ±50 ma
Freq. response; 3 db down at 15 kc
Linearity: 0.5%
Zero position control is operative for high power output ckt.

Gain — Fixed steps 1000, 500, 200, 100, 50, 20
Gain Accuracy 0.5% for D.C.
Smooth gain control covers range between fixed steps

Power Req. — 115 volts, 60 cps, approx. 50 watts

MODEL 450-1100 CARRIER PREAMPLIFIER

Carrier Freq. — 2400 cps (std.); 600, 1200, 4800 cps optional

Carrier Exc. — approx. 4.5–5 volts, depending on transducer imped.

Transducer Imped. — 100 ohms min. - 1000 ohms max.

Input Imped. — approx. 2500 ohms, incl. zero sup. ckt.

Sensitivity — 100 uv rms from transducer (output imped. 1000 ohms or less) gives 1 volt at output under max. output loading

Output — preferred circuit: between one active cathode and one reference cathode
alternate circuit: between active cathode and ground

Output Voltage Capabilities — (a) ±3 volts into 2.2K min. load
(b) ±6 volts into 5K load
(c) ±7.5 volts open ckt

Output Linearity — better than 0.2% for (a) above

Output Impedance — approx. 1000 ohms, preferred ckt., 500 ohms alternate output ckt.

Freq. Response — 3db at 20% of carrier freq.

Zero Suppression — can suppress 0 to 100% of transducer load (either sense via switch)

Power Req. — 115 volts, 50-400 cps, approx. 30 watts

always possible to abide by them. Frequently other considerations, such as produceability, economy, or foolproof reliability, conflict with the recommended practices.

Still another military problem is the armed forces' inability to hold onto competent technicians. Until Congress passes some sort of legislation, Pentagon planners see the services on a treadmill: losing technicans to private industry as fast as they can train them.

Hope for relief was seen in the development of new test instrumentation, including some types of computers, to speed the location of malfunctions. Concentration on go/no-go testers was also considered as a major contribution.

One company presented an interesting concept: the use of existing types of equipment to run a series of programmed tests for an airplane or missile. The series would include the following actions: 1) test all systems by means of special sensing elements built into the plane or missile; then 2) identify any system that is malfunctioning and execute the appropriate diagnostic test program; and finally 3) produce a punched card that identifies and locates any malfunctioning parts.

Still another proposal under discussion was the use of programmed tests for complex, interdependent systems. These tests would detect deterioration in performance, hinting at the degeneration of components, before a breakdown could occur.

—Jack Meyer

Reliability Symposium Ponders State of the Art

Closely allied to the subject of maintainability is reliability. In January engineers gathered at Washington's Statler Hotel for the Fourth National Reliability & Quality Control Symposium. Billed as "A Report to the Nation on the State of the Art in Reliability at the Start of the New Year", the symposium, rather than presenting an up-to-date report, gave its attendees a chance to chew over some well-known ideas.

After attending three days of technical sessions—with always two meetings running at the same time—a visitor came away with two clear-cut impressions:

1) Components are at the root of the reliability problem if you think only in terms of "mean time between failures." What's needed by users

MULTI-TURN

PRECISION POTENTIOMETERS

Another outstanding advance in potentiometer design by Clarostat *imagineering* . . .

Clarostat Series 55 Multi-Turn Precision Potentiometer *exceeds* all applicable MIL specifications. The new design permits up to 20% greater winding length in a given 10-turn outside diameter. Maximum protection against environmental humidity, salt spray, shock and temperature extremes.

Available in wide range of electrical and mechanical characteristics.

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Minimum runout. **Minimum** end resistance. **Minimum** "noise." **Maximum** stability. **Maximum** resolution.

Servo and bushing mountings. Panel ball bearing. Oil-impregnated sleeve rear bearing.

Center-tapped. Functional outputs obtainable by resistance-loading each side of center tap.

Tap leads welded to resistance element. Any practical number available.

Terminal leads also welded to resistance element. Gold-plated terminals.

Flexible design readily modifiable to **your** requirements.

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Controls and Resistors

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In Canada: CANADIAN MARCONI CO., LTD., TORONTO 17, ONT.

WHAT'S NEW

is up-to-date statistical life data on the essential properties of components. But must manufacturers are slow to supply such information, primarily because it's so expensive to get.

2) Engineers working in reliability are making a concentrated pitch to win new recognition of their status from management.

With the interest in component life, it was not unexpected that work in component evaluation, both here and abroad, should be brought to the attention of the symposium. R. Brewer, General Electric Co., Ltd., described a project in England to analyze vacuum-tube failures according to assembly faults, processing faults, and design faults. Brewer also compared tube life of British Services Reliable Tubes with commercial units. The result: British "reliable" tubes are about seven times better than their commercial equivalents, and nearly 20 times better than commercial tubes in general.

Joseph Kimmel, RCA, reported on a study now under way to evaluate the effects of accelerated life testing on paper dielectric capacitors. Object of the test: to provide an estimate of mean-life or failure rate. Bernard Hecht, a consultant to the Sprague Electric Co., also discussed failure rate of capacitors in accelerated life testing. Gist of Hecht's talks: by collecting life data, Sprague was able to apply Marcus Acheson's equations for predicting tube life to capacitors. Unfortunately, much of the value of Hecht's paper was dissipated by his continual emphasis on sales features of a high-reliability capacitor rather than on the technical aspects of prediction of failure rate, the title of his paper.

In another vein, an interesting concept was presented by a panel that discussed system reliability considerations. This new concept: "system effectiveness" as opposed to a limited view of reliability only. (There'll be more about this approach in a technical article in the April issue).

During the symposium, one other note of reliability came in for a lot of discussion. That was weather reliability. For the fourth straight year the symposium—sponsored jointly by the IRE Professional Group on Reliability & Quality Control, the American Society for Quality Control, the EIA Quality Acceptance Procedures Committee, and the AIEE Committee on Electronics—coincided with snow in Washington. To beat the snow pattern next year, the symposium will move north to Philadelphia.

WHAT'S NEW

CONTROL BITS

Grant of $1,200 has been made by the Foundation for Instrumentation Education & Research to Stanford University's new Aerodynamics Physical Measurements Laboratory. The fund, which was originally supplied by the North Texas Section of ISA, will be matched with a similar sum by Stanford; its use: to develop a shock tube and associated high-speed photographic equipment for taking schlieren pictures of shock waves.

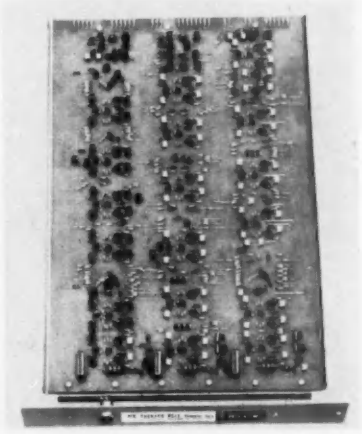
•

Federal Reserve Bank has engaged Stanford Research Institute to prepare operational performance specifications for a system to process checks automatically. The system to be proposed will conform to present recommendations of the American Bankers Association regarding the use of Magnetic Ink Character Recognition as the common machine language for automatic check processing.

•

Sperry Gyroscope Div. of Sperry Rand has started deliveries of an advanced flight control system for the Martin SeaMaster, 600-mph four-jet seaplane. The transistorized control, the SP-30, uses a newly-developed velocity servo system and angular accelerometers to sense deviations from programmed flight path.

•



Special-purpose digital computer, TRICE (Transistorized Real Time Incremental Computer, Expendable), was developed by Packard-Bell Electronics Corp. to evaluate missile performance during flight. Computer was built for U. S. Army Ordnance Ballistic Missile Agency at Redstone Arsenal. TRICE is said to be 24 times faster than any other digital computer, replaces analog computers usually used for this work.

INDUSTRY'S MOST ADVANCED DESIGN!

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Transformer

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(unmounted)

MORE CAPACITY FOR EQUAL SIZE

MODEL VT1R5—1.5 AMPERES. The rating of 1.5 amperes represents a continuous current rating at any brush setting even at full overvoltage! This "bonus" in current capacity is the result of a unique core design by Ohmite. This new component from Ohmite is made to the same high standards as the famous Ohmite resistors, rheostats, and other components. Other models in larger sizes will be announced soon.

Direct reading dial is calibrated to 120 on one side—132 on the other, for line or overvoltage connections respectively.

Here is a new component from Ohmite that will help you spark your industrial business — the new Ohmite Variable Transformer Model VT1R5. This unit is now available from stock. Other models in larger sizes will be announced soon.

STOCK AND SELL THE LINE INDUSTRIAL BUYERS KNOW AND PREFER . . . OHMITE®.

In addition to its greater capacity for equal size, the new Ohmite VARIABLE TRANSFORMER, representing industry's most advanced design, features the following quality features:

- *Heavily Plated Rhodium Brush Track* . . . Generous, nonoxidizing plating assures unsurpassed life under demanding conditions.
- *Positive Current Transfer* . . . The contact arm carries no current in this unit! A pigtail shunts the current from the brush, directly to a large copper-graphite slip ring which contacts a large area of the terminal. The spring-like contact arm provides its own completely independent pressure.
- *Rugged INTERNAL Stop* eliminates possibility of damage to contact arm and brush due to application of torque at rotation limits.
- *Ceramic Hub* . . . Mounts and aligns the contact arm, provides 3000 volts ac insulation between parts at line potential and shaft.

AVAILABLE FROM STOCK:
SPECIFICATIONS—MODEL VT1R5
INPUT VOLTAGE—120V, 60 CYCLE.
MAX. OUTPUT AT ANY BRUSH SETTING—1.5 AMPS. OUTPUT VOLTAGE—0-132—0-120.
ANGLE OF ROTATION—320°.
Includes knob, reversible dial plate, washer and nut.
Tandem assemblies available soon.

BACK VIEW

WRITE FOR BULLETIN 151

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TAP SWITCHES • TANTALUM CAPACITORS •
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AROUND THE BUSINESS LOOP

A Control Fund Speaks

Automation Shares, Inc. looks at the economy, finds it's just about ready to make a thrust out of the doldrums.

Automation Shares, Inc., a small mutual fund quartered in Washington, D. C., only began offering its portfolio of control-company stocks and bonds to investors last August. Because it does not have the necessary $1 million in net assets, it has not yet qualified for membership in the National Association of Investment Companies, the Wall Street trade group of funds of all kinds. And because it does not have an imposing battery of employees, Gilbert H. Baker and John W. Kendrick, partners in the fund, often double in brass as office manager, public relations chief, and executive in charge of answering telephones.

Still, AS has managed to be extremely vocal about the economic environment through which it has elected to guide investors, and thus about the state, present and future, of some of the most prominent control companies in business today.

A year-end report from AS, prepared by Kendrick, who is also professor of economics at George Washington University, is, therefore, of more than passing interest. And it becomes even more interesting when it is considered that something like 35 percent of the companies whose progress is constantly being examined by this fund are expected to benefit financially from the current upsurge (and recent successes) in the U.S. missile program. For these companies, and others like them, whether or not they are members of mutual funds, are eloquent spokesmen on the present economy.

• **Two viewpoints**—Last month CONTROL ENGINEERING sifted several viewpoints in weighing the possibility of a boom in this country as a result of any satellite race with Russia (CtE, Jan., p. 152). The idea was to confine the study strictly to satellites, but this, it is easy to see in retrospect, was impossible to adhere to, for a discussion involving satellites alone would have been meaningless unless the U.S. had some, too; U.S. missiles, of which there are several, had to be included to make any sense. Having included them, the study came to the conclusion that an increase in some projects and a paring, or complete disposal of others, would result in an economic status quo.

Now comes the report by Automation Shares, which, though it uses one of the sources of the CtE study (the McGraw-Hill Dept. of Economics end-of-the-year survey), predicts that "policy appraisals by the Administration and Congress, caused by Sputnik", will shortly result in an upturn in business. "Expenditures in fiscal 1959 will exceed those of the current fiscal year by at least $3 billion," Kendrick predicts. "Rockets are very costly and the step-up in this program will greatly stimulate sales and investment programs of many companies, including a larger number of our automation firms."

• **An interesting variable**—This difference in thinking is not to be taken lightly, particularly because to the argument that there will be a business upswing, AS has brought a brand-new factor, one whose development will bear watching: the replacement backlog. "A major reason why I think business fixed investment will be heading up by the second half of 1958," Kendrick said, "is the growing volume of necessary replacement. This reason is seldom stressed by forecasters, but it is important. Remember that the investment boom in equipment that followed World War II got well under way in 1947-48. From the tenth to the twelfth year after such capital outlay, the replacement curve rises sharply. That means that right now replacement needs are mounting. Undoubtedly, many replacement projects are being temporarily deferred in expectation of further favorable adjustments in prices of equipment and costs of borrowing to pay for it.

"The continuing growth of the replacement backlog will eventually cause a sharp increase in capital outlays—probably beginning in the latter part of 1958, following some further economic readjustments earlier in that year, which will stimulate the appropriation by management of more funds for that purpose, although actual expenditures will lag by some months.

"Much of this outlay involves de-

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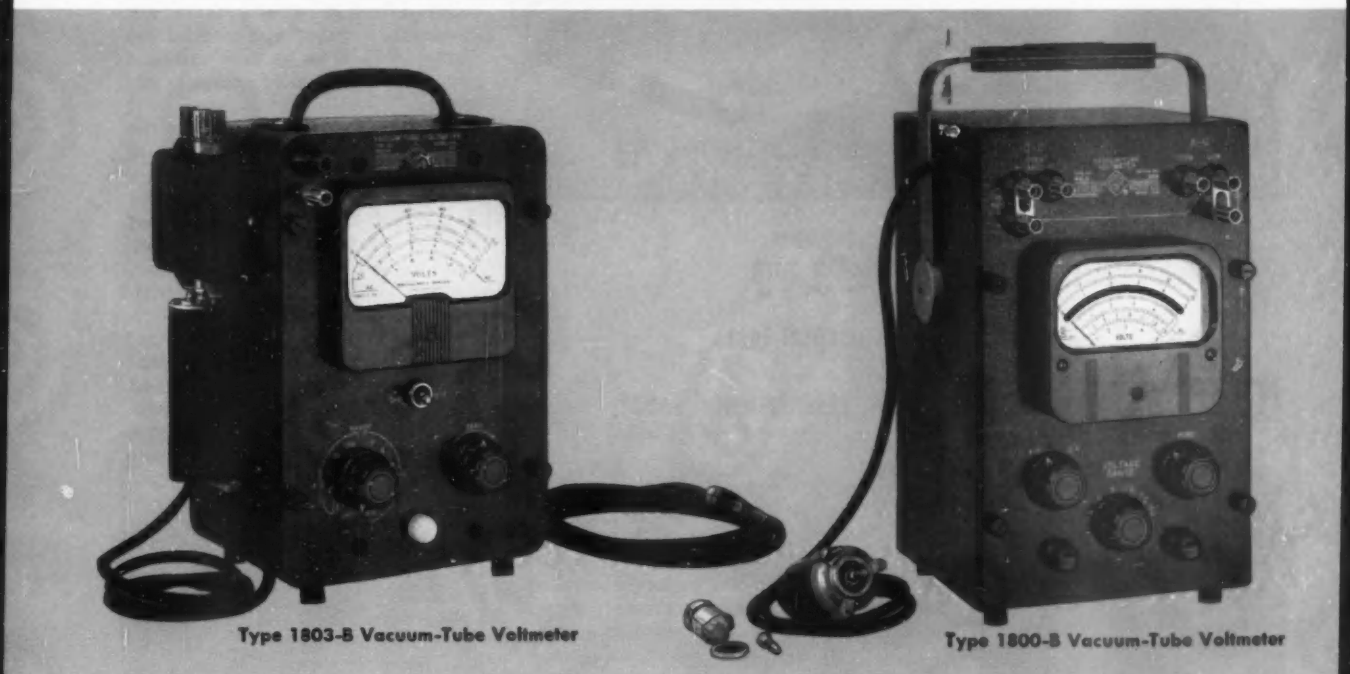
If you check your voltmeters for calibration periodically, you will find that those bearing the General Radio trademark *remain* within specified limits. Each G-R voltmeter is backed by a two-year warranty which, in addition to certifying materials and workmanship, guarantees that the instrument will perform in *full accordance with specifications* for a minimum of two years. Why not buy G-R and get reliability as well as performance?



Type 1803-B Vacuum-Tube Voltmeter

Ranges: AC; 0.1 to 150 volts in 5 ranges; attached 10:1 multiplier extends readings to 1500 volts.
DC; 0.02 to 500 volts in 6 ranges.

Accuracy: AC; ±3% of full scale, subject to frequency correction above 50 Mc (curve supplied); ±4% of full scale with multiplier.
DC; ±3% of full scale up to 50v, ±4% on 150 and 500 volt ranges.

Frequency Response: Flat within ±1 db to 150 Mc, resonance at approximately 430 Mc. Multiplier response flat within ±2% up to 40 kc.

Input Impedance:
AC; 7.7 MΩ in parallel with 10 μμf
DC; 111 MΩ. Open-grid input obtained by unsoldering internal connection.

Additional Features: Completely shielded probe — polarity switch — internal calibration control — probe cable stores inside instrument.

Price: $225

Type 1800-B Vacuum-Tube Voltmeter

Ranges: AC; 0.1 to 150 volts in 6 ranges
DC; 0.01 to 150 volts in 6 ranges.
Accessory multipliers available to extend a-c and d-c ranges to 1500 volts.

Accuracy: AC and DC; ±2% of full scale. Illuminated meter scale, knife-edge pointer, and mirror insure precise reading under all conditions.

Frequency Response: Flat within ±1 db to 500 Mc without need of probe disassembly, or external capacitors. Resonance occurs at about 1050 Mc; frequency correction curve supplied.

Stability: Separate "balancing" diode insures stability on a-c ranges. Successively higher ranges are obtained by adding amplifier degeneration, making calibration essentially independent of tube transconductance changes. These features are not found in many voltmeters.

Power Supply Regulation: No "wandering" zero — thorough two-stage regulation gives complete independence from line voltage fluctuations. Upon zeroing on 0.5v range, no further resetting required.

Input Impedance:
AC; 25MΩ in parallel with 3.1 μμf
DC; 2 values, 10 MΩ and open-grid input.

Additional Features: Thoroughly shielded amplifier circuit and probe affords excellent accuracy in strong r-f fields—instrument may be grounded for safety in measurements above ground — probe plugs into standard binding posts; coaxial adaptor provided.

Price: $435

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WHAT'S NEW

velopment of new and improved automation equipment and systems, and other capital goods, that will hasten obsolescence and add to replacement demand. The heads of some companies manufacturing automation equipment have predicted that their sales will be larger in 1958 than in 1957, despite the current sag in total equipment sales."

• **Says upswing is near**—Lately, Kendrick said, there has been a business recession and a bear market in stocks, but "it is my view that the prices of many automation stocks, which have fallen to more realistic and sometimes bargain levels in recent months, will resume their major uptrends by the Spring of 1958, or as their excellent prospects become more generally recognized."

As of Nov. 25, 1957, these were the principal "automation" companies in the AS portfolio: Beckman Instruments, Borg Warner, Burroughs Corp., Clark Controller, Consolidated Electrodynamics, Electronic Associates, Emerson Electric, Link Belt, Mechanical Handling Systems, Robertshaw-Fulton, Servomechanisms, Texas Instruments, and Westinghouse. While this is an impressive partial listing, it is important to understand that these companies can hold memberships in other funds, too. In other words, Automation Shares has not cornered the market on control makers. Companies whose membership in AS is pending include American Electronics, American Machine & Foundry, Clary Corp., Coleman, IBM, IT&T, Lear, W. L. Maxson, Norden-Ketay, Sperry Rand, and Telecomputing.

As far as long-range prospects go, Kendrick said, "Our projections indicate that by 1965 the sales of a representative group of automation companies will more than triple—but this is merely our assessment of probabilities, and is, of course, not a certainty. Continuing increases in wage-rates relative to prices of capital goods and the interest rate is a powerful incentive to continued step-ups in purchases of automation equipment in an expanding number of industries."

• **Local boom already on**—Short of polling the various managers of the other mutual funds dealing in "automation" stocks, it is hard to say for sure how they would take to these opinions by AS, though chances are they would go along for the most part. It is a fact, however, that a boom, local as yet and logically situated, is already taking

(Continued on page 166)

A pot you can bet on

When you're playing with a hot system and the stakes are high . . . raise!

Raise as high as 150° C . . . and HELIPOT® series 5000 precision potentiometers will still operate continuously with 1 watt dissipation.

Although it's only 1/2 inch in diameter and weighs but 0.3 ounce, on this pot you can bet the limit. You'll hold the winning hand with these five high cards off the top of the Helipot deck:

- stainless steel construction
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- 500 to 100,000 ohms standard resistance range
- one-piece housing
- all-metal card for uniform heat dissipation

When the chips are down, these three standard models will strengthen your hand: the bushing-mount precision 5001, the servo-mount precision 5002, the trimming-type 5016.

There's a house full of specs the series 5000 meets or beats: JAN-R-19(7), MIL-E-5272A, NAS-710, MIL-R-12934A, MIL-E-5400, MIL-R-19518, MIL Std 202.

The straight inside story on the new series 5000 is available in data file 22G.

Helipot Corporation, Newport Beach, California
a division of Beckman Instruments, Inc.
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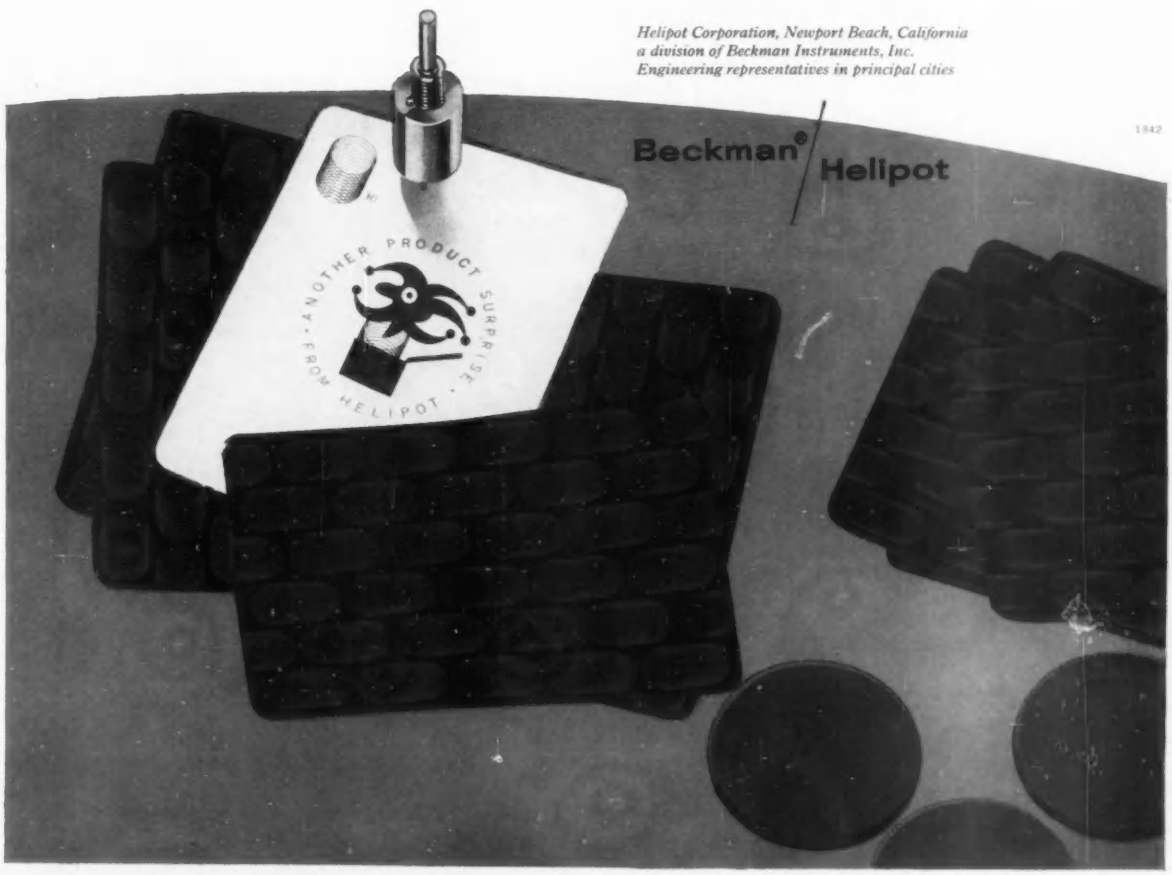

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Standard or special— Industrial Timer makes rapid deliveries on all models

Sometimes you need a standard model timer . . . other times you need a special. Either way we can give you the extra rapid service you may need because of the efficient way we design, manufacture and stock timers for industrial applications.

To meet *all* of the widely varying needs of our customers we manufacture a complete line of timers in the four broad classifications illustrated here:

1. TIME DELAY TIMERS
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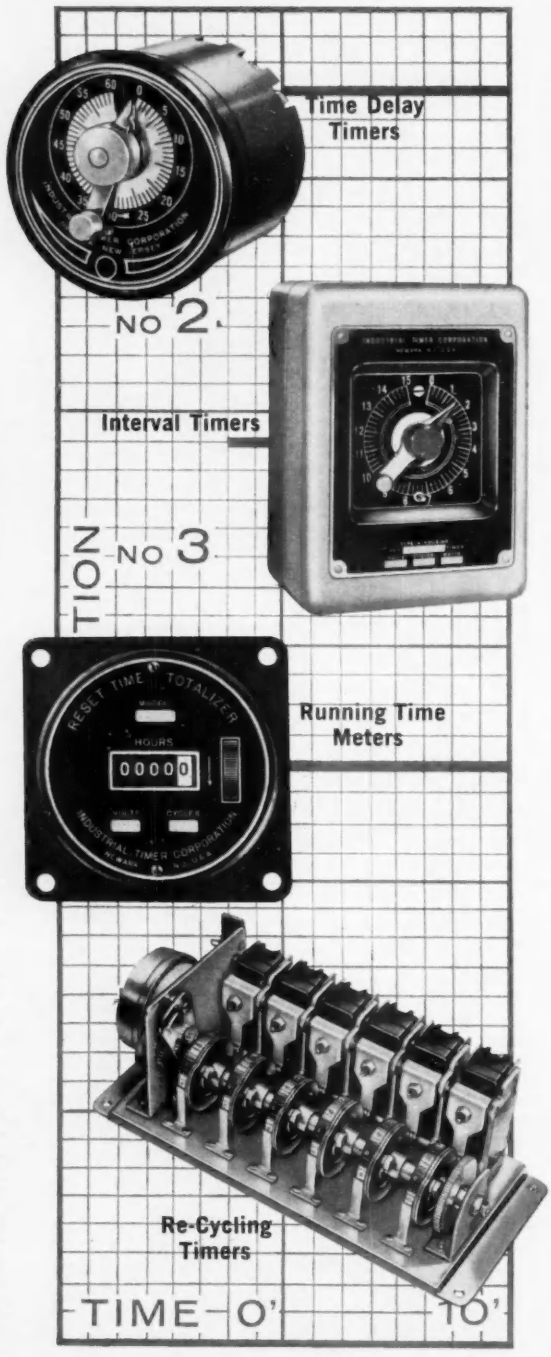
From these we have already developed 20 basic types which can be combined in endless number of ways . . . to date, our engineers have combined them into over 1000 different models. So what might seem to be a special timer requirement to you, will very often be a standard timer in our large stock, and that is the reason we have the ability to fill special orders so quickly. And as far as standard timers are concerned we can give overnight service if necessary.

So, for the utmost in all-round service depend on us for this outstanding combination: deliveries "Immediate on Standards . . . First on Specials".



Speed up your automatic control projects— profit by our timing application experience

No need to let timing problems delay you in your automatic control projects when you can place them with us and get faster solutions. Even though no two automatic control jobs are ever exactly alike, and even though the timer requirements of each are very different we have established an excellent record in helping out in these situations.

20 years of experience in analyzing complex timer applications has provided us with the special knowledge required to give our customers the right answer in near-record time.

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Extra special automatic control timer — this calls for original designing. Our engineers will go right to work and get the job done. That's the way we grow and we like it.

Whatever your control problem, you have everything to gain by submitting it to our timer specialists. They'll come up with the answer — almost with the speed of automatic control itself.

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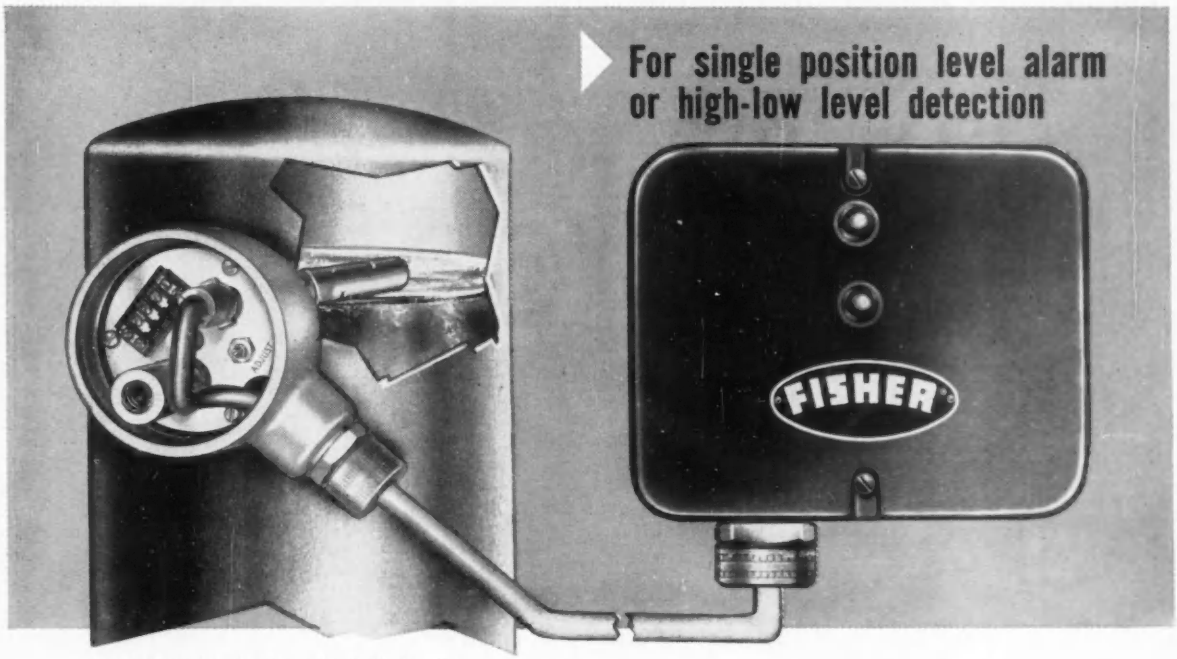
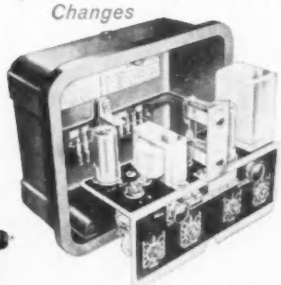
The Capaci-trol—a capacitance type level position detector



Type 2414W with sensing element installed horizontally for high level detection.

- *Compact Construction*
- *No Moving Parts*
- *Pressures up to 2500 psi*
- *Requires only 110 a. c. to operate*
- *Unaffected by Supply Voltage Variations*
- *Temperature Application Range From −50° F. to +150° F.*
- *Unaffected by Ambient Temperature Changes*

The Capaci-Trol is an electronic-electric level alarm and control unit for detection of level position in vessels—either as single point level detection for high or low level alarm applications or for high-low differential gap level detections. Units operate with power frequencies of 60 cycles utilizing a capacitance bridge circuit in conjunction with a rugged and durable Thyratron tube. Requiring only 110 a. c. supply voltage, the Capaci-Trol is completely self-contained and has no moving parts. The electrical output can be used to operate solenoid valves, motor starters, indicator lights, alarms, etc. All components of the Capaci-Trol are of the highest quality available, insuring maximum dependability and long life.



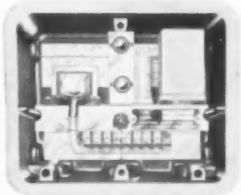
Type 2408W control unit featuring plug-in chassis.

AVAILABLE IN TWO MODELS

TYPE 2408W DIFFERENTIAL GAP CONTROLLER. The Type 2408W can be used in a wide range of conducting liquids for two-position control of level. Components are mounted on a plug-in chassis housed in a weather-proof aluminum case. Sensing elements available in lengths from 6" to 36" which is connected to remote control unit with coaxial cable. Maximum differential gap—80% of total length of sensing element. Minimum differential gap—0.5".

TYPE 2414W HIGH OR LOW LEVEL ALARM. The Type 2414W High or Low Level Alarm unit, as shown above, is designed for use in both conducting and non-conducting liquids. This, in general, includes the range from aqueous solutions to petroleum oils. Weather-proof housings are used for all components. Thyratron tube is in head portion of sensing element, thus requiring only standard wire in connecting to control case.

Write for Bulletin F-2408 for complete information



Type 2414W remote case contains power supply, relay and lights. Thyratron tube and level adjustment located in conduit on top of sensing element.

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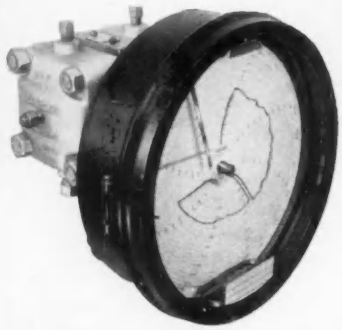
Differential Pressure Cell Transmitters

Complete line includes air-operated and electric-operated d/p Cell Transmitters covering ranges from 0-20" to 0-850" of water; working pressures up to 4000 psi.

Type 13A d/p Cell Transmitter

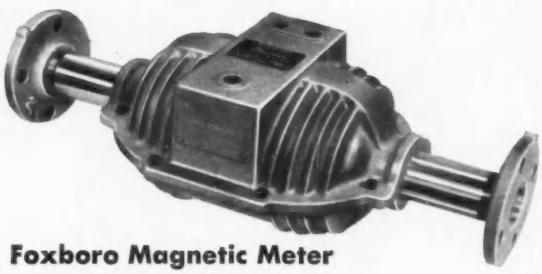
- Positive Overrange Protection—up to full 1500 lbs. rating
- Fully Adjustable Ranges—0-20" to 0-850" water
- Automatic Internal Damping — fast, stable measurement
- Simplicity—easiest, lowest-cost installation, lowest maintenance



Type 37 Diaphragm Meter

- Uses no mercury
- Positive overrange protection at static pressures up to 2000 psi
- Exclusive Features — Built-in temperature compensation never needs change or adjustment; twin-spiral range springs readily accessible for easy range changing
- Unique packless drive bar transmits linear motion to pen arm
- Ranges of 20", 50", 100", 200"; available in round or rectangular cases; 316 stainless or carbon steel body

PROBLEM



Foxboro Magnetic Meter

- Measures Fluid Velocity Directly
- Adds No Pressure Drop
- Uniform Flow Scale
- Overall Accuracy Better than 1% of Range Over Entire Scale
- Full Accuracy Sustained Even on Liquids Other Meters Can't Handle — even sand and water slurries

THERE ARE two logical reasons why Foxboro Instrumentation assures you optimum results in measurement or control of process fluid streams. First: Foxboro offers the widest variety of measuring and controlling devices . . . the right equipment for every application. For example, only Foxboro offers all these basic meter types: differential pressure cell flow transmitters, magnetic meters, mercury meters, and weir meters. Second: Foxboro provides 45 years of engineering experience in every phase of fluid mechanics.

From the simplest general utility-type instrument to complex automatic ratio control systems, you get highest accuracy, efficiency, and economy. Whenever you have a flow problem involving liquids, vapors, gases or slurries — in pipes, ducts, or channels, you can solve it best by specifying Foxboro.

Only a few instruments are described on these pages. For full details, or for specific information on your problem, contact your nearby Foxboro Field Engineer, or write The Foxboro Company, 362 Norfolk St., Foxboro, Mass.

FOXBORO

REG. U. S. PAT. OFF.

FIRST IN FLOW

Mercury Type Meters

- Permanent Full-Scale Meter Accuracy — exclusive segmental lever design provides linear transmission from float to pen
- High-Powered Pen Drive—large float with long travel
- Minimum Ambient Temperature Effects — float located in high pressure chamber
- Ranges from 2" to 400" of water; working pressures up to 5000 psi

Other Foxboro Flow Instrumentation

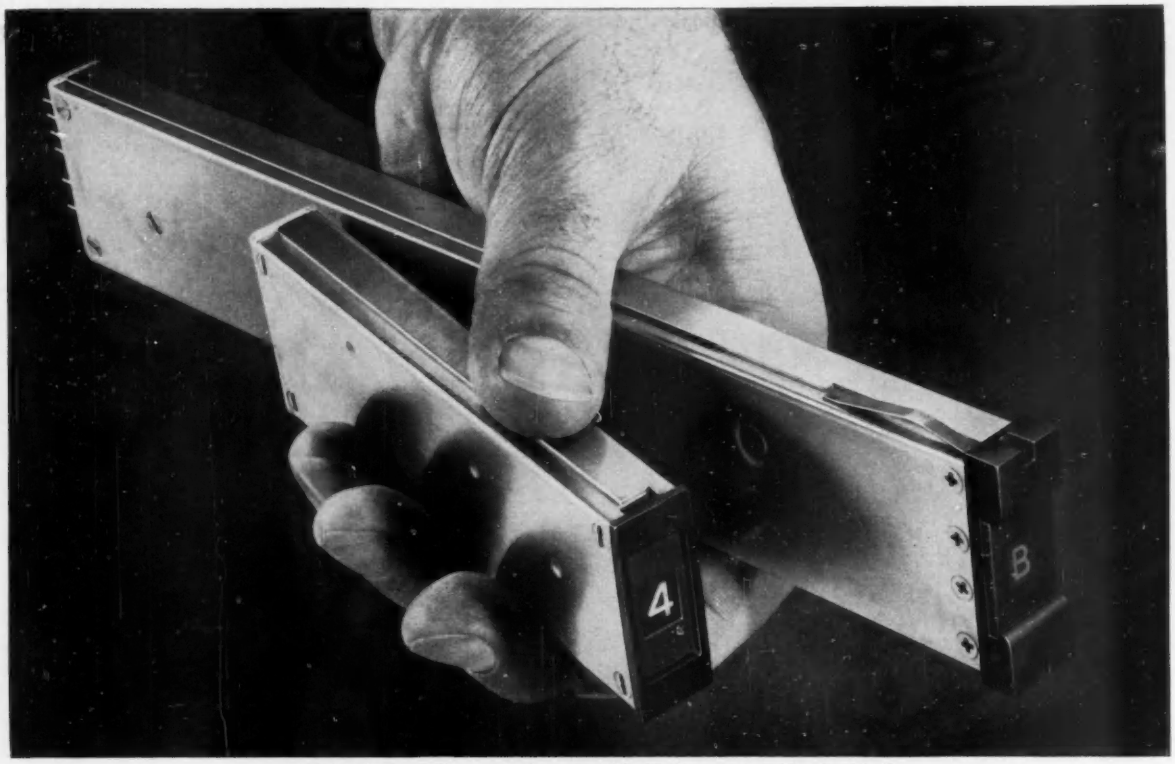
Float-and-Cable Type Meters

Electric or Pneumatic Type Rotameters

Electric, Pneumatic, and Mechanical Integrators

Planimeters

All Primary Elements, Valves, and Accessories required for complete flow measurement and control systems



Digital indicator (left) can display a possible 16 characters and is about half the size of the Alpha-numerical indicator (right) which displays 64 characters.

UNION INDICATORS
permit direct readout of binary data

UNION Digital and Alpha-numerical indicators are controlled by binary code signals employing a minimum number of control wires, and respond to simultaneous binary switching combinations.

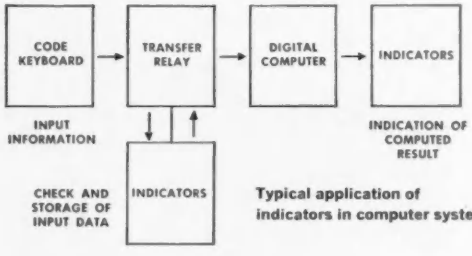
These indicators are electro-mechanical, D.C.-operated, readout devices for displaying characters in accordance with a predetermined code. The character display may be made to suit user's requirements.

Indicators are designed for plug-in mounting in a row so that data or messages of any desired length can be stored, displayed or transmitted at will. The indicators can be applied to the output of digital computers, teletype receiving equipment in conjunction with a buffer storage unit, telemetering systems, or wherever data needs to be displayed.

Two important features of these indicators are their inherent storage and transmitting characteristics which provide for data entry and retransmission. The indicators can be used to accept data from a source, free the source for other programs, and disseminate the data from one indicator to another as required. For each binary bit stored, an external relay can be eliminated.

UNION indicators have provided economic and reliable advantages in data display applications associated with Air Traffic Control, Navigation, Telemetering, Fire Control and similar Airborne and Surface Instrumentation displays.

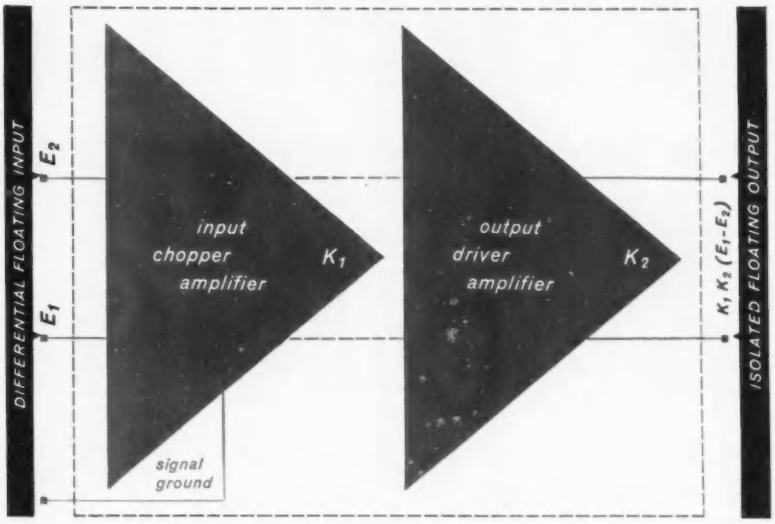
Write for Bulletin No. 1015 for complete information.



Typical application of indicators in computer systems.

UNION SWITCH & SIGNAL
DIVISION OF WESTINGHOUSE AIR BRAKE COMPANY
PITTSBURGH 18, PENNSYLVANIA

New! KIN TEL's true differential DC amplifier...

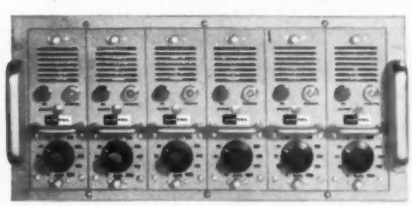


completely isolates input from output!

AMPLIFY MICROVOLT-LEVEL DATA SIGNALS
New transistorized differential DC amplifiers provide extremely high common-mode rejection, very low drift, high output capability, and excellent stability and linearity... all unaffected by load or gain changes. Ideal for thermocouple amplification, they eliminate ground loop problems; allow the use of a common transducer power supply; permit longer cable runs; drive grounded, ungrounded or balanced loads, and can be used inverting or non-inverting. The 114A is the *perfect instrumentation amplifier.*

BRIEF SPECIFICATIONS – 114A DIFFERENTIAL DC AMPLIFIER

- 120 db common-mode rejection from DC to 60 cps.
- Gain of 10 to 1000 in 5 steps, continuous variation between steps.
- Gain accuracy 1.0% DC 10 cps, 3% to 30 cps, 3 db down at 120 cps.
- DC gain stability and linearity 0.1%.
- <5 μv noise; <5 μv drift at gain of 100 or above.
- Maximum output capability 10V at 10 MA.
- 100 K ohm input, <1 ohm output Z (min. load res. 20 ohms, max. load cap. 1.0 μf).



Six KIN TEL amplifiers in compact 19" rack mountable module.

STANDARD WIDEBAND DC AMPLIFIERS can be used single-ended or for floating input applications. An operational version permits the user to employ his own feedback networks to limit bandwidth, generate transfer functions, obtain specific gains and perform integrations. Specifications for the 111 series, Wideband DC Amplifiers include: <2 μv drift; <5 μv noise. ±35 V, ±40 MA output. 100 K ohm input, 1 ohm output Z; 1.0 μf allowable output cable capacity. 0 to 1000 gain in ten steps, with continuous 1 to 2 times variation of each step. Gain accuracy (freq. response) ±1.0% DC to 2 KC, <3 db down at 40 KC.

ALL KIN TEL DC AMPLIFIERS feature integral power supplies, convenient plug-in mounting and KIN TEL's proven chopper feedback amplifier circuitry for unsurpassed stability, accuracy and reliability. They have accumulated over 500 years of operating time, and in one installation alone have logged over a million hours of trouble-free operation. Records like this are the result of stringent quality controls, thorough testing and calibration, and years of experience in the design and manufacture of thousands of chopper stabilized DC amplifiers.

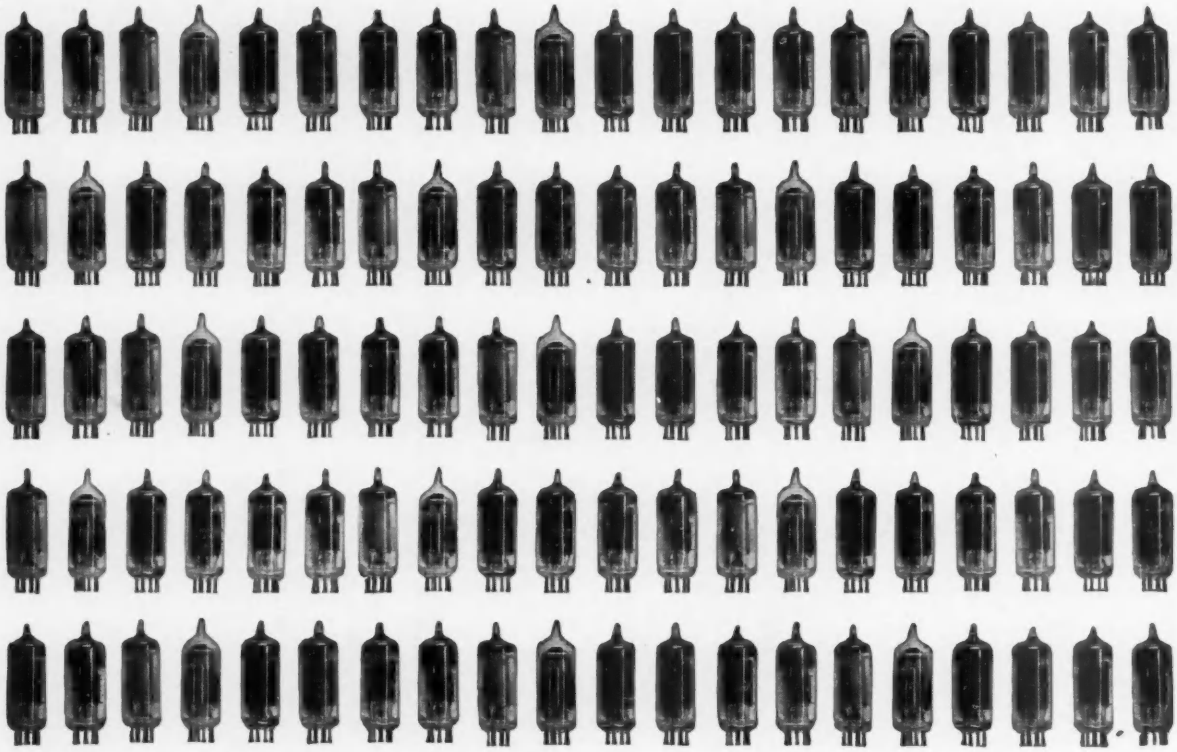
FOR GREATER ACCURACY, SIMPLICITY, RELIABILITY, and the elimination of carrier system balance problems, replace complex carrier systems with a KIN TEL packaged "plug-in" DC instrumentation system – complete from input transducer to output device.

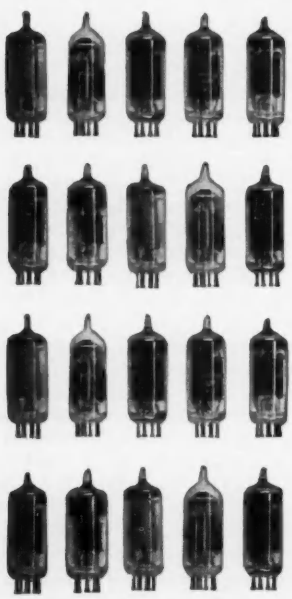
Over 10,000 KIN TEL instruments in use today!

Representatives in all major cities.
Write today for demonstration or literature.
5725 Kearny Villa Road, San Diego 11, California, Phone: BRowning 7-6700.

KIN TEL

A Division of Cohu Electronics Inc.





*NOW—from a single stock Sola voltage regulator—±1% regulation of all these 6.3v tube filaments**

Now, you can supply *banks* of 6.3v electron tubes with ±1% regulated filament voltage from a single Sola Constant Voltage Filament Transformer. This static-magnetic stabilizer, designed for compact mounting as a manufacturer's component, is available in five stock ratings ranging from 5 to 25 amperes.

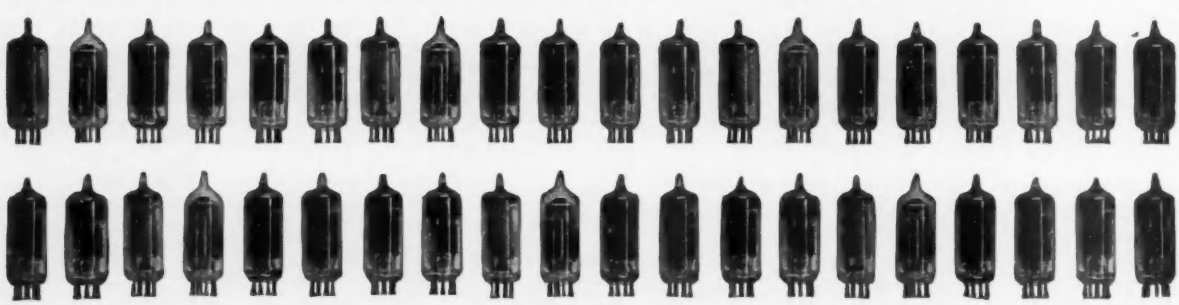
The Sola Constant Voltage Filament Transformer assures superior performance, reliability, and long life for the tubes it operates. The capacitor, an integral part of the Sola Constant Voltage principle, is supplied separately for external mounting, allowing greater flexibility in physical layout.

For further information on regulated 6.3v filament supply, contact your area representative or write for Circular CVF-269.

**Filament current drawn by 160 electron tubes with filament ratings of .15a each equals 24a— within the capacity of Sola's 25a Constant Voltage Filament Transformer.*

SOLA *Constant Voltage* **TRANSFORMERS**

Sola Electric Co. • 4633 W. 16th Street • Chicago 50, Illinois

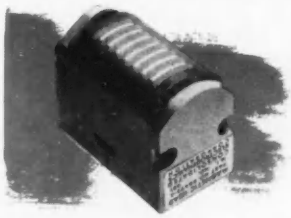


only

DataTape

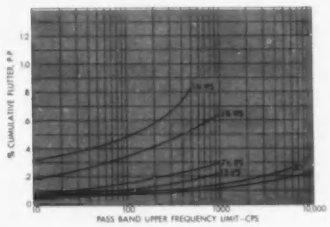
offers

all-metal-surface magnetic heads

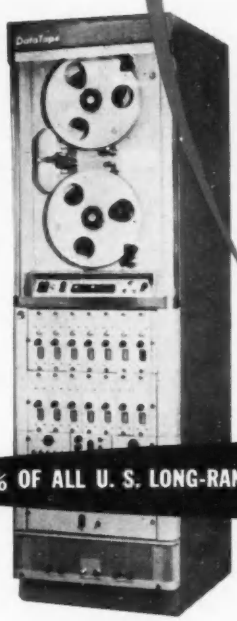


No more drop-outs or loss of high-frequency response because of oxide build-up on heads. All-metal-surface... rather than conventional metal-plastic combinations... promotes a self-cleaning action and minimizes head wear.

lower flutter even at low tape speeds

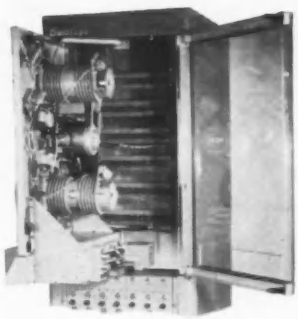


Cumulative flutter at 1⅞ and 3¾ ips is approximately one-half that found in other tape equipment. CEC is first to achieve the low-speed flutter characteristics shown at left. Chart shows flutter recorded at 30 ips and played back at speeds indicated.



complete front access

The 5-752 is the only recorder/reproducer offering complete front access to all incoming and outgoing signal, control, and power interconnections. Access to internal amplifier circuits is through standard connectors on front of unit. All electronics are mounted on drawer slides.



CEC *magnetic tape recorder/reproducer system*

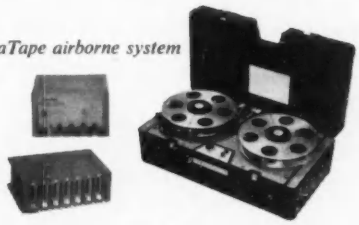
90% OF ALL U. S. LONG-RANGE MISSILE TEST FLIGHTS ARE RECORDED ON CEC DATATAPE

Simplify your data problems. Get instantaneous playback up to 14 tape tracks with CEC's 5-752 Recorder/Reproducer System with simultaneous recording or reproducing of separate signals on one-inch tape. Seven different types of plug-in amplifiers record and reproduce in Analog, PDM, or FM modes. Contact your nearby CEC field office, or write for Bulletin CEC 1576-X13.

TYPICAL APPLICATIONS – Telemetering from Missiles and Aircraft, including FM sub-carrier telemetering. Wind-Tunnel Testing. Jet and Rocket Engine Testing. Studies of Shock and Vibration. Mobile and stationary Structural Testing: ships, trains, etc. Static and Dynamic Testing: airframes and components. Sound measurements: all types of analyses, including, sonar, medical research.

Continuous loop transport

DataTape airborne system



DataTape Division

Consolidated Electrodynamics

300 North Sierra Madre Villa, Pasadena, California

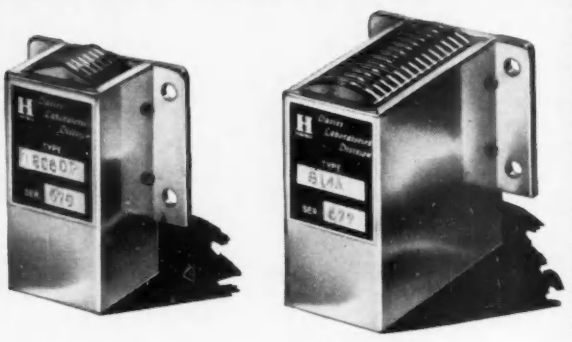
OFFICES IN PRINCIPAL CITIES THROUGHOUT THE WORLD

Multi-track magnetic recording reproducing heads...

Laboratory-designed, precision-built by Davies

Series	Track Data		Crosstalk (db)	Number of Tracks for Various Tape Widths							
	Width (Mils)	Spacing C to C (Mils)		¼	½	¾	1	1¼	1½	1¾	2
700	50	140	–60*	2	4	5	7	9	11	13	14
800	40	125	–60*	2	4	6	8	10	12	14	16
1000	40	100	–55*	3	5	8	10	13	15	18	20
1200	32	85	–50*	3	6	9	12	15	18	21	24
1300	26	78	–40**	3	6	10	13	16	19	23	26
1400	40	72	–40**	3	7	10	14	17	21	24	28
S1400	32	70	–40**	3	7	10	14	17	21	24	28
1600	32	62	–35**	4	8	12	16	20	24	28	32
2000	20	50	–35**	5	10	15	20	25	30	35	40

*For Direct Recording, 1000cps
**For Digital Pulse Recording



MODEL 1206 DP MODEL 814 A

Davies multi-track recording and reproducing heads for magnetic tape data recording are offered in a wide selection of designs for every practical tape service.

Davies single-stack heads are precisely aligned for those applications requiring coincidence of time and phase among tracks. Gap alignment is held to within ± 0.1 mil per inch of tape width.

For services requiring a large number of tracks, but where time and phase displacement can be tolerated, Davies 700, 800 and 1000 Series Heads can be interleaved to provide 14, 16, or 20 tracks on 1" tape.

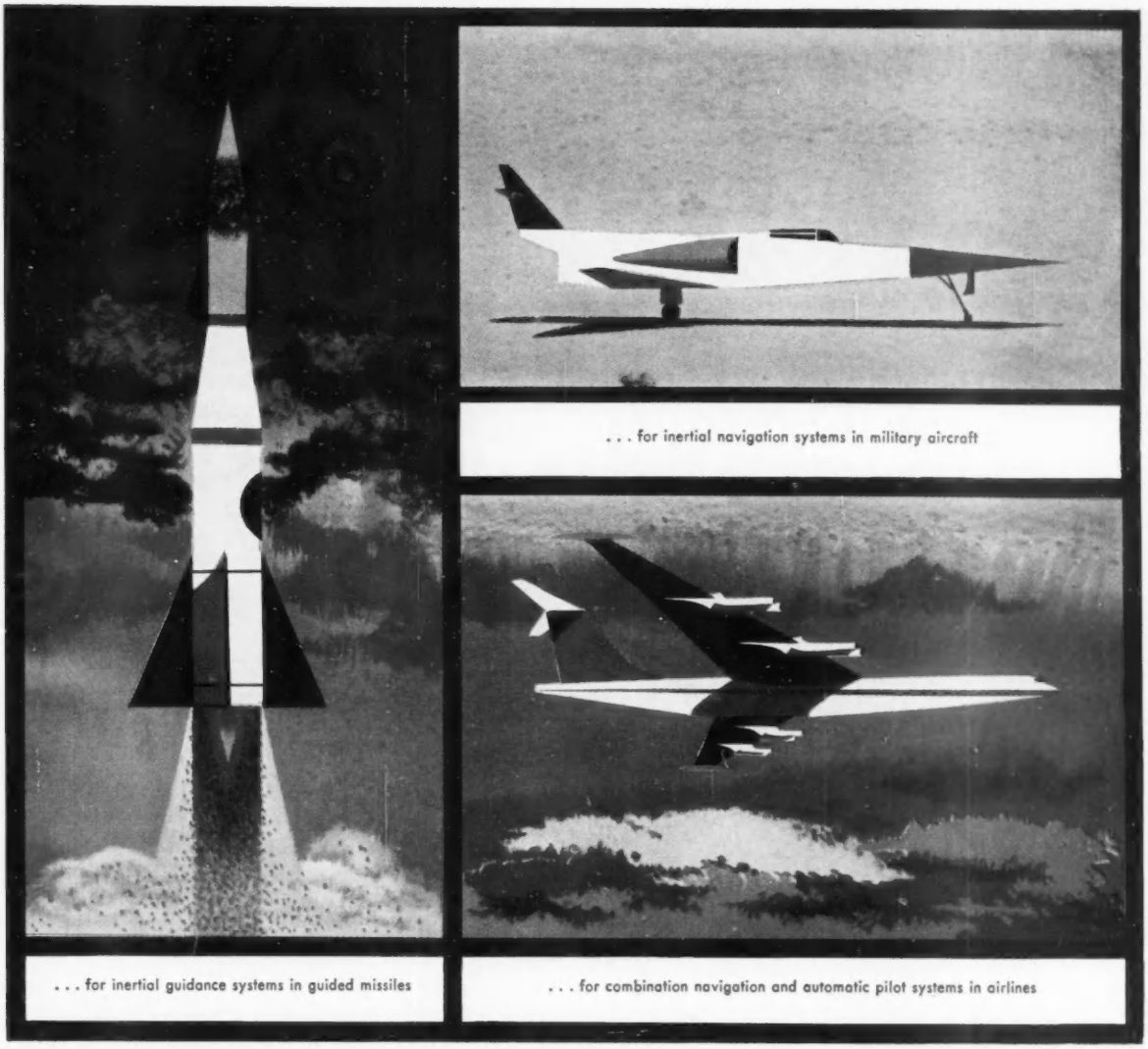
All-metal tape contact area on Models with the "P" designation (1206 DP above) essentially eliminate oxide build-up at high tape speeds.

In all types, plastic encapsulation protects and preserves the characteristics, even under adverse environmental conditions such as shock, vibration and extremes of temperature and humidity.

Select the appropriate recording/reproducing head from the condensed chart. Complete technical and application information may be obtained by writing Minneapolis-Honeywell Regulator Co., Davies Laboratories Division, 10721 Hanna Street, Beltsville, Md.

Honeywell

H HONEYWELL DAVIES LABORATORIES DIVISION



. . . for inertial navigation systems in military aircraft

. . . for inertial guidance systems in guided missiles

. . . for combination navigation and automatic pilot systems in airlines

See AC

. . . for the only precision-built

gyroscopes

now in volume production

The first units of floated rate-integrating, single-degree-of-freedom gyros began coming off the AC production lines in June of 1957. AC gyros are built to such precision standards that they can sense rates of rotation so slight that one revolution would take several years to complete. What's more, AC gyros have withstood as much as 5,000 to 7,000 consecutive hours of operation without significant loss of efficiency. Actual test information is available to qualified manufacturers. Immediate delivery of: 75×10^6; 10×10^6; 2×10^5; 1×10^4. —If you are an engineer and have an electrical, mechanical or electronic background and might be interested in working with AC in Milwaukee, write Mr. Cecil E. Sundeen, Supervisor of Technical Employment, Dept. H, 1925 E. Kenilworth, Milwaukee 1, Wisconsin, **AC . . . the Electronics Division of General Motors.**

Afterburner Fuel Controls • Bombing Navigational Computers • Emergency Fuel Controls • Gun-Bomb-Rocket Sights • Gyro-Accelerometers • Gyroscopes Inertial Guidance Systems • Manifold Air Pressure Regulators • Speed Sensitive Switches • Speed Sensors • Three-Way Selector Valves • Torquemeters

When You Need Reliable Control of Thermal Operations

you need Adlake *mercury-to-mercury relays*

Match these Adlake abilities against your needs:

- **Perfect function under vibration**
- **Perfect snap-action. No pitting, burning, sticking**
- **No dust, dirt or moisture intrusion—hermetically factory-sealed**
- **Time delay characteristics fixed, unchangeable.**
- **Quiet. Chatterless. Require no maintenance whatever.**

Our engineers will be happy to help you solve your control problem. No obligation. Just write THE ADAMS & WESTLAKE COMPANY, 1181 North Michigan, Elkhart, Indiana. Original and largest manufacturers of plunger-type relays.

How to simulate an enemy attack

(or recreate vibrations, noises, failures or highway profiles)

Sometimes pretending can be better than the real thing – or at least cheaper. (by millions or billions). For such purposes magnetic tape is a master mimic with a talent for recreating or synthesizing almost any physical, mechanical or electrical effects.

Simulation control console showing the Ampex FR-100 behind

CHECKOUT AND PERSONNEL TRAINING WITH "INDESTRUCTIBLE TARGETS"

U. S. Army's Land Based Talos unit* at White Sands Proving Ground tests its weapon system for response to "enemy engagements." Missiles and suitable targets could be a frightful expense – limited in number at best – and destructive of much of the evidence of performance. But magnetic tape bypasses the hardware carnage by providing the signals that the missile would "see."

** Developed by RCA under U.S. Navy Sponsorship.*

The Talos Missile "flies" its collision trajectory toward an enemy on tape. Correlation between target signals and weapon-system response is recorded. Without the missile ever leaving the ground, the weapon system proves its ability to find the aerial invader.

Similarly, tapes are used to train personnel. Complex "enemy engagements" on tape actuate the instruments and indicators requiring human judgment. Crew reactions are recorded for study and improvement.

TAPE IS VERSATILE AND REPEATABLE

Magnetic tape is able to make these complex simulations because its output is electrical. When tape signals are suitably amplified, they are identical to the voltages that occur in the sensing, guidance and instrument systems of the missile and launcher. Tape can reproduce almost any desired analog or digital pattern. Successive replays will be completely identical.

For the Army's Talos installation in New Mexico, tapes are prepared on the east coast. Compatibility, an important feature of Ampex Tape Recorders, makes it possible to send these "enemy attacks" across the country on reels of tape with assurance that correct tests will be made.

Simulation from magnetic tape is used by others in innumerable ways. It records vibrations in aircraft and vehicles to drive shake tables that test components. It records operating sequences or performance standards to test production assemblies. It reproduces sounds. And tape has even been used to reproduce mountain highway grades to test truck axles under laboratory observation.

Can magnetic tape simulation be of use to you, and may we advise you on your specific problems? Would you like this informative ad series mailed direct? For either request, write Dept. HH-12.

INSTRUMENTATION DIVISION
AMPEX CORPORATION
FIRST IN MAGNETIC TAPE INSTRUMENTATION
934 CHARTER STREET · REDWOOD CITY, CALIFORNIA

District offices serving all areas of the United States and Canada; Foreign Representatives in countries around the world.

MAGNETIC TAPE APPLICATIONS BY AMPEX

12

ONE OF A SERIES

Series FR-100

Model FR-300 Digital

Model FR-400 Digital

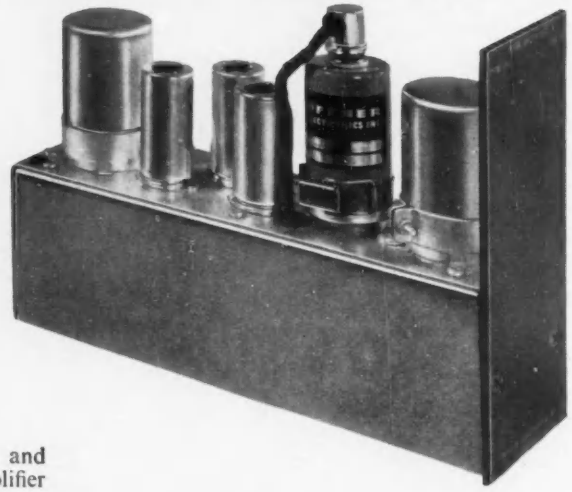
Series 800 Mobile and Airborne

Series FL-100 Loop Recorders

Model MR-100 Missile Recorder

THE OFFNER TYPE 190

DIFFERENTIAL DATA AMPLIFIER



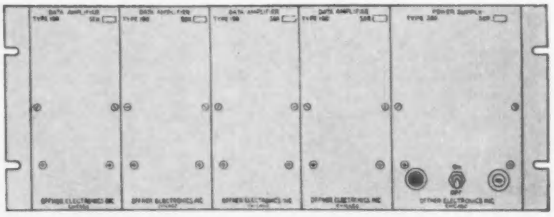
d-c Amplifier with zero drift and 1/100th percent gain stability

For amplification of thermocouple, strain gage, and similar low level signals the Type 190 Data Amplifier provides a combination of features available in no other amplifier:

- ☆ **Infinite rejection of common-mode d-c signals**
- ☆ **One microvolt input resolution**
- ☆ **Gain stability of 0.01%**
- ☆ **Rapid step input response**
- ☆ **Linearity of 0.05%**

The true differential response of the Type 190 provides increased accuracy and simplified installation for data reduction, control, and similar applications. With infinite rejection of common d-c signals, and a rejection ratio at 60 cps of the order of a half million, errors due to ground currents are completely eliminated, and pickup problems greatly diminished.

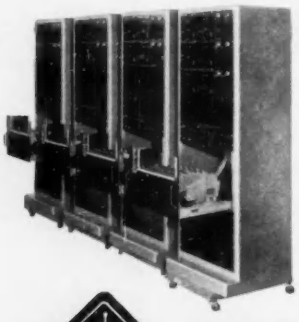
The Type 190 is designed for fixed-gain operation from low impedance sources, into high impedance load. Gain may be set at values ranging from 160 to 1200. Amplifier characteristics are unchanged at ambients from −67°F to +170°F.



Four Type 190 Amplifiers mounted in BM190 modular rack unit with Type 390 power supply.

Price of Type 190 Amplifier.....$325
Type 390 Power Supply, for up to four Type 190 Amplifiers.....$250
Type BM190 Rack Unit for four Type 190 Amplifiers and Type 390 Power Supply.....$140

Ask for bulletin No. 572 giving full technical information



OFFNER DYNOGRAPH Direct-Writing Oscillograph

Zero-drift d-c recorder with microvolt sensitivity.
One amplifier type covers all requirements.
Models for one to 19 channels.
Rectilinear or curvilinear recording.

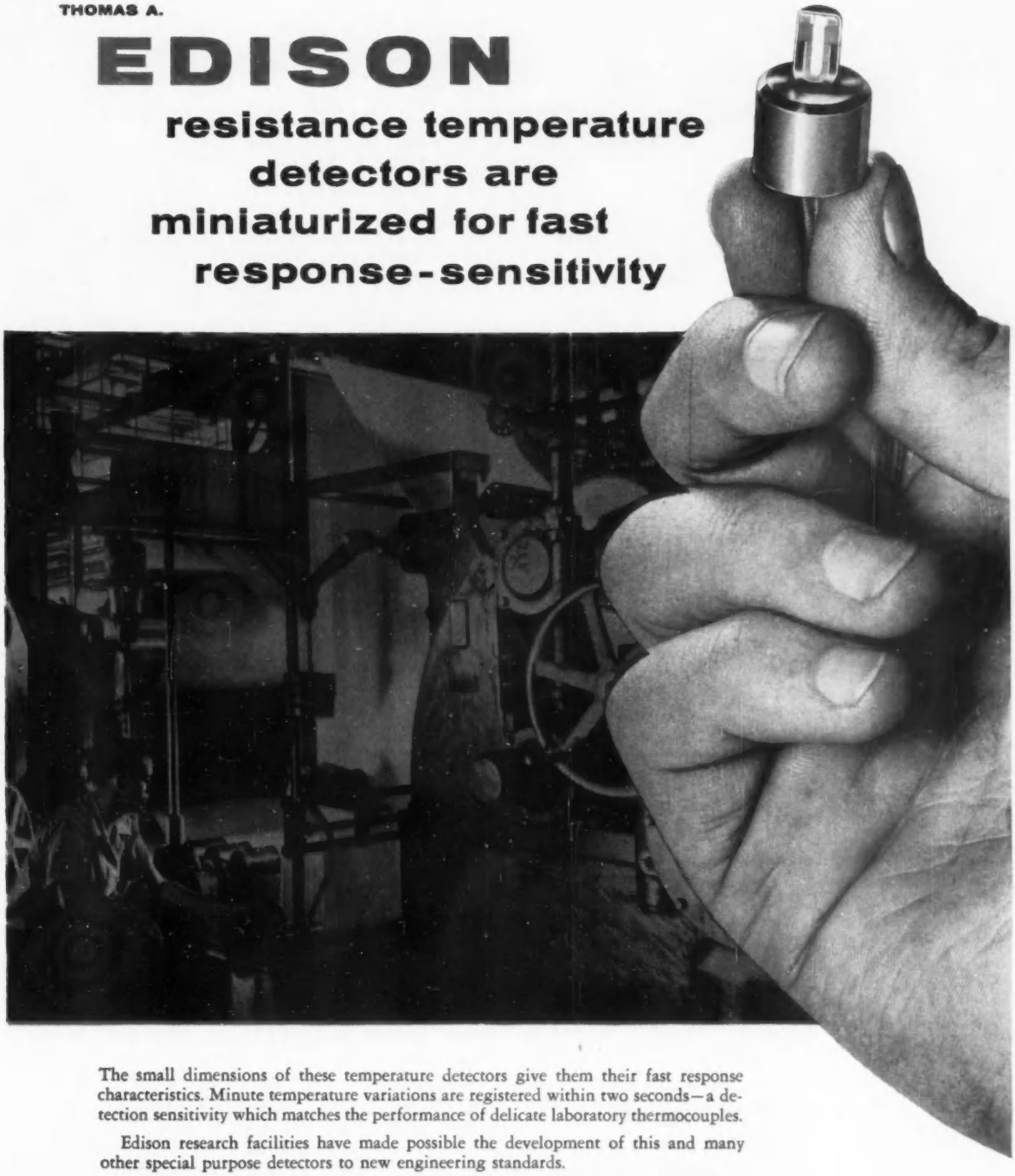
Ask for bulletin No. L-861

OFFNER ELECTRONICS INC.
5316 N. Kedzie Avenue, Chicago 25, U.S.A.

THOMAS A.

EDISON

resistance temperature detectors are miniaturized for fast response-sensitivity



The small dimensions of these temperature detectors give them their fast response characteristics. Minute temperature variations are registered within two seconds—a detection sensitivity which matches the performance of delicate laboratory thermocouples.

Edison research facilities have made possible the development of this and many other special purpose detectors to new engineering standards.

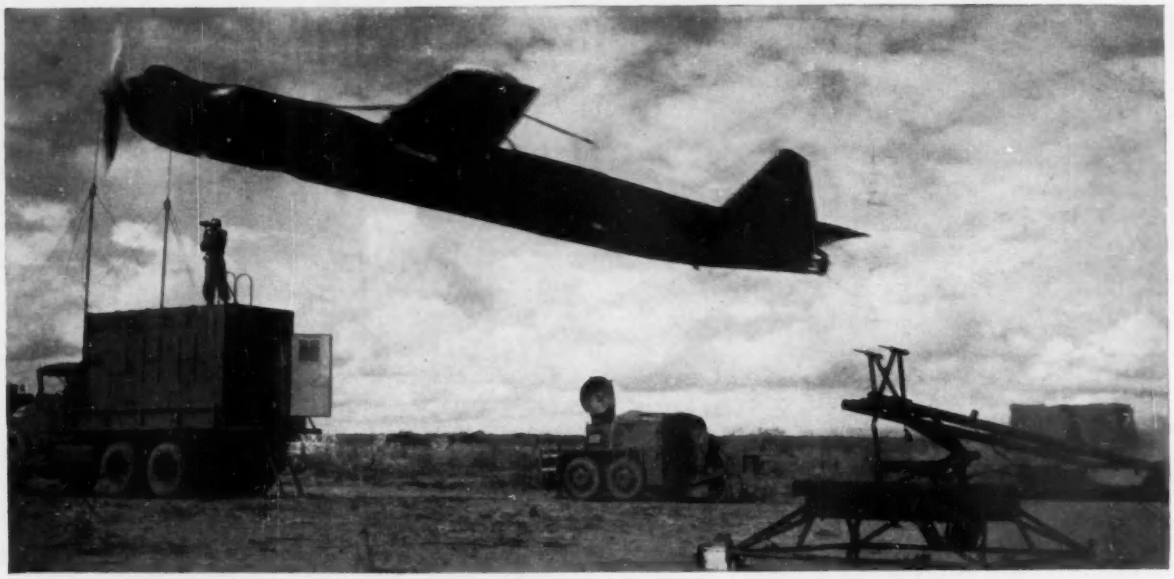
Designed to measure oil film temperatures, these units have been miniaturized to the point where they can be positioned in direct contact with bearing oil film in a wide variety of applications.

For complete information on Edison Resistance Temperature Detectors, write for Bulletin No. 3016.

Thomas A. Edison Industries
INSTRUMENT DIVISION

38 LAKESIDE AVENUE, WEST ORANGE, N. J.

McGRAW EDISON



Aerial drone being launched in test at Fort Huachuca. Remotely controlled by van equipment, it serves as a "flying camera" to spot enemy movements and installations.

U. S. ARMY SIGNAL CORPS DEVELOPS ELECTRONICS FOR ATOMIC-AGE AT FORT HUACHUCA PROVING GROUND

Fort Huachuca, once a sleepy cavalry post, has come of age in the last few years. When the United States Army Electronic Proving Ground was established here in early 1954, this mile-high post was set upon a new trail marked by electron tubes, transistors, radar antennae, and television cameras.

Nestled against the base of the rugged Huachuca mountains about 100 miles south of Tuscon, its 70,000 plus acres are a beehive of electronic activity under United States Army Signal Corps direction. The many types of different terrain are ideal for the testing of electronic equipment.

Nearly 5,000 military personnel and approximately 2,000 civilian employees, many of them highly skilled scientists, are engaged in work at the Proving Ground.

The new look in defense is placing heavier burdens on the United States Army Signal Corps. This, of course, means more communications with new doctrines suited for employment in atomic war. The Combat Development Department at the Proving Ground has been experimenting along these lines. A new area system of battlefield communication designed to meet the threat of mass destruction from nuclear attack is now in the planning stages.

Meanwhile, the Signal Communications Department is conducting tests on both standard and experimental United States Army Signal Corps equipment to determine their future with the new look in defense. Under atomic attack, the use of extensive wires will not be practical. More radio communication is the answer, but ways to put more channels on radio frequency must be found.

With the spread-out of troops under atomic attack, increased surveillance of combat areas is a necessity. The Combat Surveillance Department of USAEPG is presently developing and testing a surveillance system with devices on the ground and in the air to bring reconnaissance and fire control information to the field commander.

Another important Proving Ground product is the "Flying Camera." A high speed camera is mounted in the fuselage of a remote-controlled drone aircraft. The aircraft is launched into the air by means of jet assist. When its mission is completed, the drone parachutes to the ground near the original launching site. Its up-to-the-minute pictures are developed, and the troops proceed to hit the pin-pointed areas of resistance.

* * *

These are just a few of the many projects under way at Fort Huachuca, helping to keep our country's military offense and defense the world's best.

ANNOUNCING THE SERVOTRAN!

a revolutionary new variable speed drive

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ELECTRO-MECHANICAL INSTRUMENTS

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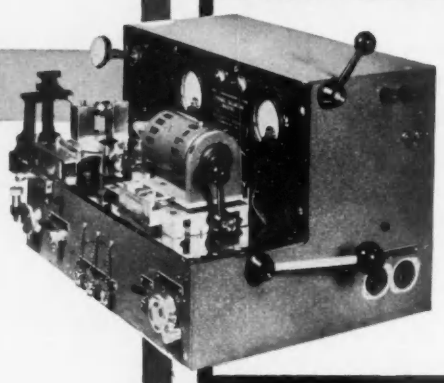
DYNAMIC UNBALANCE

of miniature high speed gyro rotors

Detailed information is in Instrument Data Sheet 211, available upon request to Technical Literature Section.

decker DYNAMIC BALANCER



without removing the rotor from the mount

Even miniature missile type gyro rotors can be balanced in 6 to 10 minutes with the DECKER DYNAMIC BALANCER. And ultimate balance is generally limited only by the quality of the rotor bearings.

Designed specifically for high speed rotors requiring maximum possible precision of balance, the Model 211 Dynamic Balancer is capable of handling any rotor which may be electrically driven at 10,500 rpm or higher.

The Balancer offers, on a single portable chassis, everything needed for precision dynamic balancing. Included are the necessary equipment for rotor mounting, measurement, and location of unbalance, plus a precise metered automatic drill for unbalance correction.

- **Maintains laboratory type precision balance on a production basis**
- **Does not require a skilled technician**
- **Automatic marking of point of unbalance**
- **Drilling performed without removing rotor.**
- **Precise indication of degree of unbalance**
- **Automatic speed control**
- **Rapid run up to proper speed**
- **Completely self contained and portable (11" x 15" x 21")**
- **Rapid work change over**

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You'll receive the kind of engineering and manufacturing you'd be proud to call your own. (Many times in 17 years of ordnance and instrument work we've improved upon the original design of devices we've been assigned to produce.)

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INTELLIGENT ENGINEERING AND PRECISION MANUFACTURING

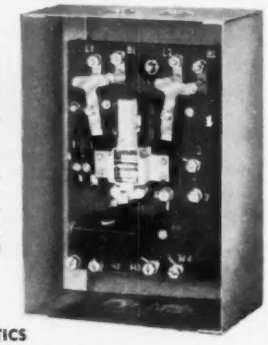
ASCO time delay relay handles motor loads directly!

field adjustable from ½ to 6 seconds . . . for all voltages

A rugged power type relay, with power relay electrical characteristics (see table), enables this ASCO Time Delay Unit to handle motor loads directly. Alternate designs require two devices: a time delay relay and a contactor. ASCO provides both in one reliable unit!

A simple screwdriver adjustment permits any time delay on dropout from ½ to 6 seconds . . . and the ASCO designed adapter makes the device suitable for 240, 480, and 600 volts, 60 cycles (120 volts without the adapter). The unit is also available for other frequencies and for D-C.

Multiple contacts are available in various combinations permitting the use of one relay, where with other time delay devices additional relaying would be required.



Time Delay Relay in NEMA 1A cabinet—note adapter mounted beneath the relay. The three units, cabinet, time delay relay and adapter, form a time delay combination for any standard A-C voltage.

ASCO Time Delay Relays can be furnished with fixed or adjustable time delays . . . for time delay when the circuit is energized or de-energized . . . for A-C operation at frequencies from 25 to 2000 cycles, and for D-C.

ELECTRICAL CHARACTERISTICS

Maximum Current on Make.....300 Amps.
Continuous Current Carrying Capacity.....25 Amps.

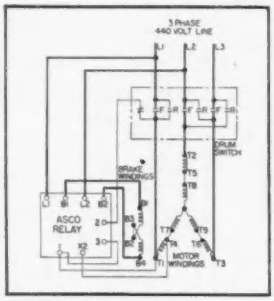
A-C Voltage	Break Currents at Maximum Operations per Minute of:		
	1	10	20
120	150	70	50
240	115	60	45
480	65	45	30
600	50	35	25

Based on approximately 50% "on time". Where percent "on time" is less than 50%, higher ratings can be applied.

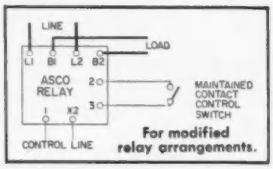
OTHER FEATURES

• Double Break Silver Contacts with Wiping Action • Clapper Type Magnet with Oilite Bearings at Pivot • Vacuum impregnated coil • Low Loss Silicon Steel Magnet Frame • Telephone Quality Capacitor Conforming to Spec. No. JAN-C-62, manufactured and tested to ASCO specifications • Selenium Rectifiers used Conservatively • Creepage Distance Well in Excess of NEMA and Underwriters' Laboratory Requirements for 600 Volts.

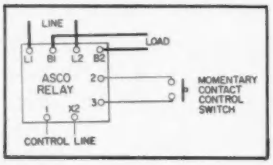
APPLICATIONS



For Brake Winding Motors — Each time the motor controller is operated to the "motor stop" position, this relay closes, energizing the brake winding to stop the motor. The relay disconnects the brake winding after a pre-set interval.



For "Single Pulse" Time Delay— Each momentary pushbutton closing causes the relay to close, connecting the line to the controlled equipment. The relay automatically disconnects the circuit ½ to 6 seconds later, depending upon the setting.



For "Repeated Cycling" Time Delay — Repeated relay closings and dropouts at ½ - 6 second intervals are provided with the external contact closed.

In Automatic Controls — instantaneous acting control relays quite often introduce complications of instability, variations in cycling, accelerated contact erosion, hunting of associated relays and unnecessary shutdowns due to transient conditions. These conditions can be overcome with ASCO Time Delay Relays.

Time Delay Relays are only part of the complete line of Relays offered by ASCO. Catalog 57-S4 lists:

- **MAGNETICALLY HELD RELAYS**
  AC or DC . . . Normally Open . . . Normally Closed . . . Double Throw
- **MECHANICALLY HELD RELAYS**
  AC or DC . . . All Pole Combinations
- **SPECIALIZED RELAYS, INCLUDING:**
  . . . Reverse Current
  . . . Close Differential
  . . . Current Type Welding
  . . . Electronic
  . . . Modified Arrangements

Write for your copy of "Relays by ASCO"— Catalog 57-S4.

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FRontier 7-4600

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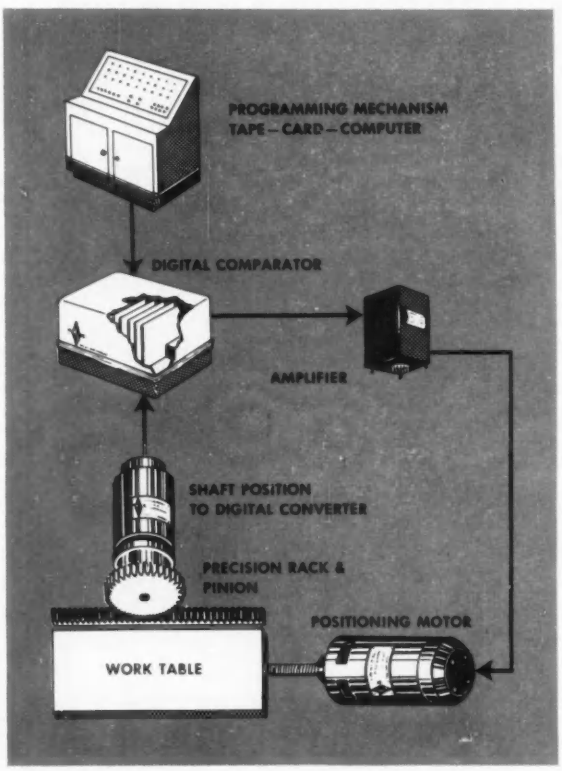
Absolute Position Control For Machine Tools

Norden-Ketay is now producing an all digital machine tool positioning system that is as precise as a number.

The servo control loop illustrated has a familiar look but a new concept is involved. The command is a number (binary coded decimal) the coordinate of where the machine is to go. The position feedback is a number . . . the coordinate of the location of the machine. The digital comparator subtracts the two numbers and creates an error signal to position the drive motor. When the final position is reached, the two numbers are identical . . . the difference is precisely zero.



Norden-Ketay also produces machine tool positioning systems utilizing synchros and, Inductosyn®

®Manufactured by Norden-Ketay Corporation under license.

The following characteristics are inherent in this type of machine tool control:

- Each thousandth of an inch has its own unique address. A false position due to dropping a count, calibration drift or momentary power failure cannot occur.
- Program preparation is the ultimate in simplicity. Only final position coordinates need be recorded. Auxiliary commands such as direction or slow-down need not be supplied.
- The machine can prepare its own program by automatically recording on tape the position obtained by a skilled machinist. No new skill is required.
- Digital display of position in illuminated decimal numbers is continuously available.
- Accuracy of .001 inch is standard. A self-contained measurement reference in the form of a precision rack makes the control accuracy independent of the tool.
- Any number of axis may be controlled simultaneously.
- Slewing rates as fast as 500 inches per minute are permissible.

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NORDEN KETAY

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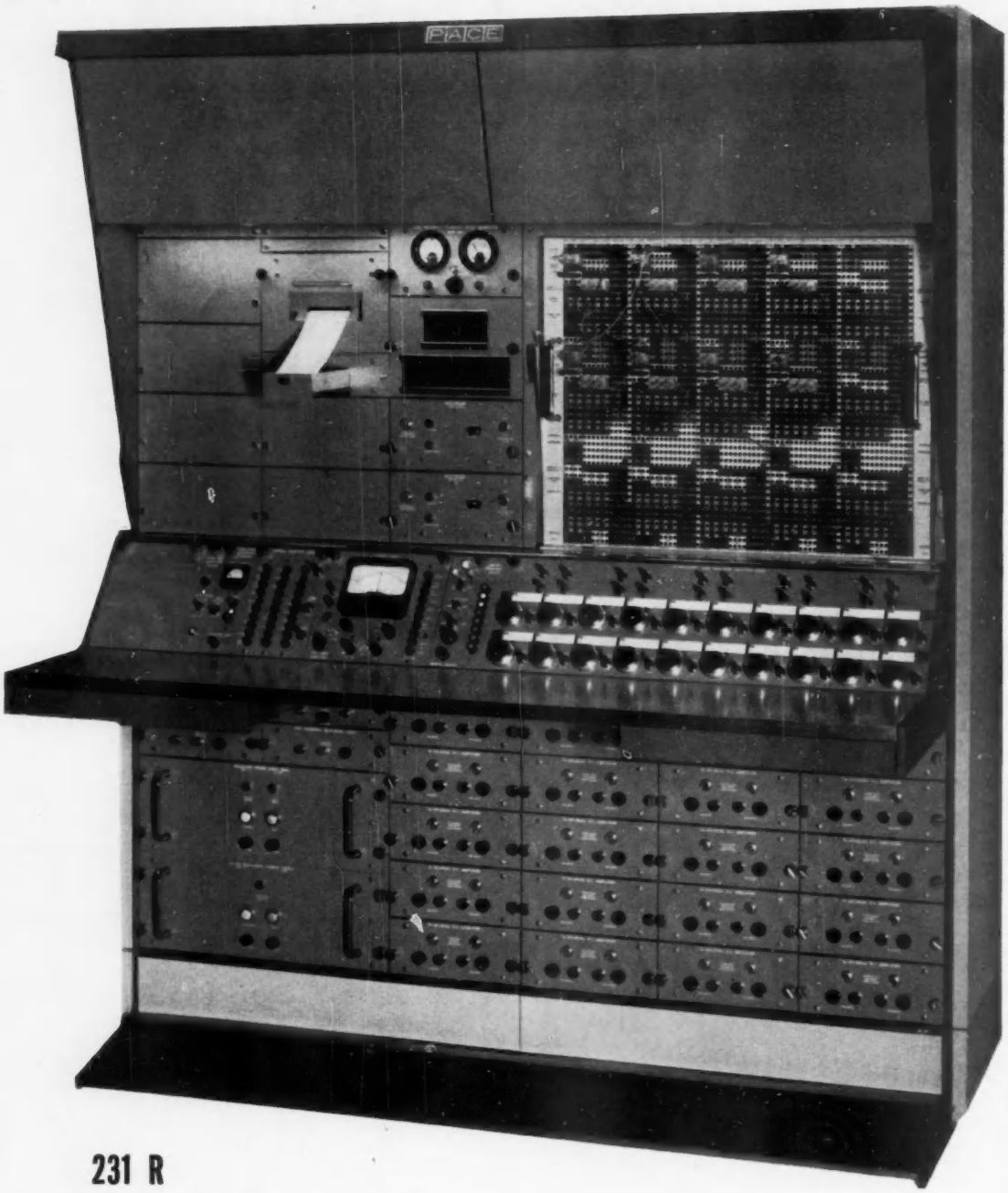
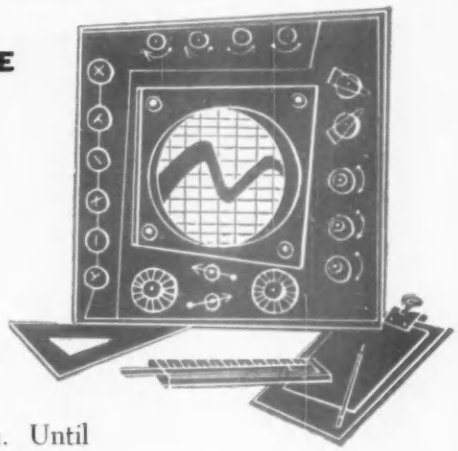


231 R

Symbol of the greatest advance in analog computing techniques——announcing PACE Analog Computer Console 231 R. This console incorporates new and exclusive features that enable it to set new standards in the art of analog computing for speed, precision, and reliability. For full information, write for bulletin number CG-116, Electronic Associates, Inc., Long Branch, N. J.

Visit our booth #1202-8, IRE Show, March 24 to 27



The Spacemen Boometh

This year the space scientist comes into his own. Until recently, even in scientific circles, there's been some question whether he was a real technologist or an offshoot of science fiction. But the Russian sputniks and now a concentrated U.S. space program have put him in the spotlight.

ARS skyrockets

Look what's happening to the American Rocket Society. Founded in 1932 by a handful of enthusiasts, ARS' membership stayed small over the first 20 years, barely topped 1,000 loyal devotees. Then along came missiles and membership jumped to 4,600 by the end of 1956. Last year a whopping 50-percent increase sent it to 7,000 (while ARS income doubled); and this year the society expects its best year in history.

There's other evidence, too. At the University of California last month, a new post-graduate lecture series in space technology started. And in Washington, pressures seem sure to force the establishment of a separate, high-level agency (probably along the lines of the Atomic Energy Commission) to handle all space-flight programs. Although space projects now in the mill will likely stay with the armed services, which started them, congressmen will probably insist that the agency be completely divorced from the Pentagon.

Brains instead of raw materials

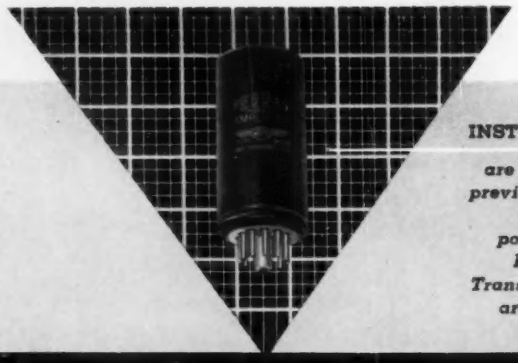
All this portends major activity for control engineers and control companies (CtE, Jan. '58, p. 99). For both missiles and space projects put more emphasis on brains and less on the mountains of raw materials associated with conventional weapons like planes and tanks. Two urgent puzzling areas: control—of fuel and guidance—and instrumentation to test delicate guidance systems and to track the space vehicle after launching.

Such projects will require money. And the space projects being talked about today carry king-sized price tags. Here are some estimated costs you hear:

- to develop an anti-missile missile, $6 to 8 billion
- to put a manned satellite into space, $5 to 7 billion
- to send a manned rocket to the moon, $5 to 7 billion
- to establish interplanetary travel, $15 to 20 billion

Shoot the moon

Time schedules for such projects are also being proposed. Shoots at the moon, for instance, are being predicted by 1960-1961. Air Force missile men say they could come sooner if the U.S. wanted to launch a crash program (and there have been

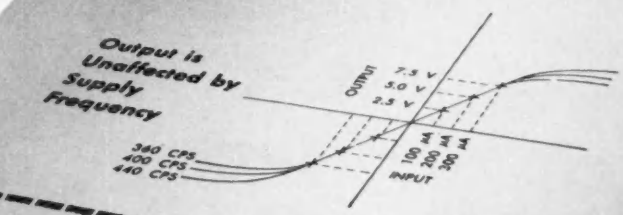


INSTRUMENT-TYPE MAGNETIC AMPLIFIERS

are being held to closer production tolerances than previously so as to make these units even more useful to you. They are used in the computing portions of high-performance instruments because of their unusual linearity and stability. Transfer Characteristic of Airpax Ferrac amplifiers are little affected by supply voltage or frequency.

DC to DC Magnetic Amplifier for Precision Instruments

As with all magnetic amplifiers, Ferrac amplifiers operate directly from the AC generator thereby eliminating the weight of DC power supplies necessary with vacuum tube or transistor amplifiers. The two input control windings are fully insulated from each other, from the power, and from the output. Thus the amplifier can be used with signals that require floating grounds.



AMPLIFIER CHARACTERISTICS

INPUT: Two independent control windings.

OUTPUT: Unfiltered DC linear ± 7.5 DC volts into 1000 ohms.

GAINS: Typical full-scale inputs are: 75 μa, 150 μa, or 300 μa.

ENVIRONMENT: Ferrac amplifiers are rated for operation − 55C to + 85C, vibrations of 10 G at 10 to 2000 CPS, 30G shoke of 11 mspc duration. Units are hermetically sealed.

DESIGNERS AIRPAX PRODUCTS COMPANY ENGINEERS

Airpax Products Company, Seminole Division, Fort Lauderdale, Florida

reports that the Russians will try such a shoot this year). These same spokesmen say the Air Force could make a moon shoot within nine months if they got the go-ahead signal now. It would mean using existing equipment, probably a Thor IRBM for the first stage, boosted by other rockets in second, third, and additional stages.

Military men also predict there could be manned stations on the moon within 15 to 20 years. One Pentagon planner said the moon is "the most valuable military base we can get".

Moon pattern

That's probably the reason there's going to be plenty of effort concentrated on moon projects. The experts say the pattern will probably go like this. First, there will be attempts to shoot an instrumented rocket—weighing from 25 to 50 lb—close to the moon to obtain technical data. Next, an effort will be made to hit the moon with a rocket. Then the space scientists will try to put a satellite in orbit around the moon. They'll follow this by trying to orbit a manned rocket. And finally landings on the moon will be attempted.

The key factors in the moon landings are accuracy and thrust. Lighter, more accurate and reliable guidance systems are needed. One scientist painted this picture of what the guidance system would have to do to land a vehicle on the moon: at final burnout, it would have to control accuracy in speed within 75 ft per sec and angularity to within 1 deg.

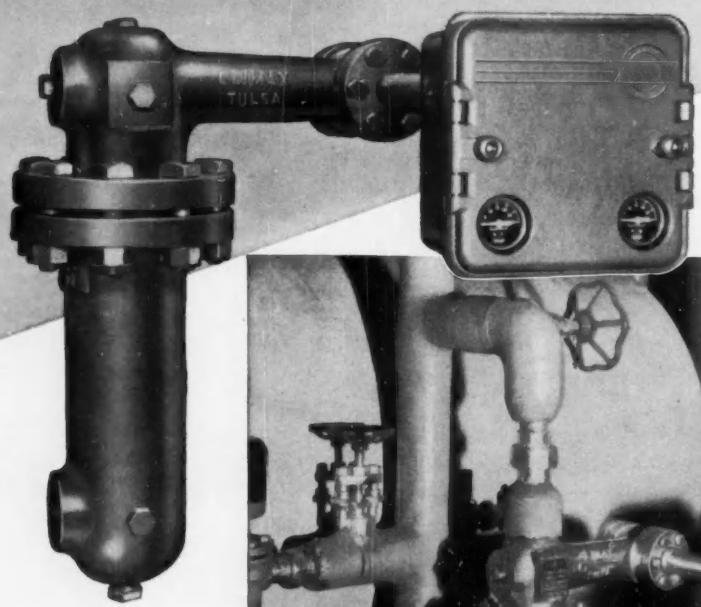
Manned satellites

Running parallel in importance to the moon program is a manned satellite project. Although there hasn't been the publicity on this project that IGY satellites have received, the Air Force does have a definite program under way. It consists of sending manned vehicles higher and higher into space until they orbit around the earth.

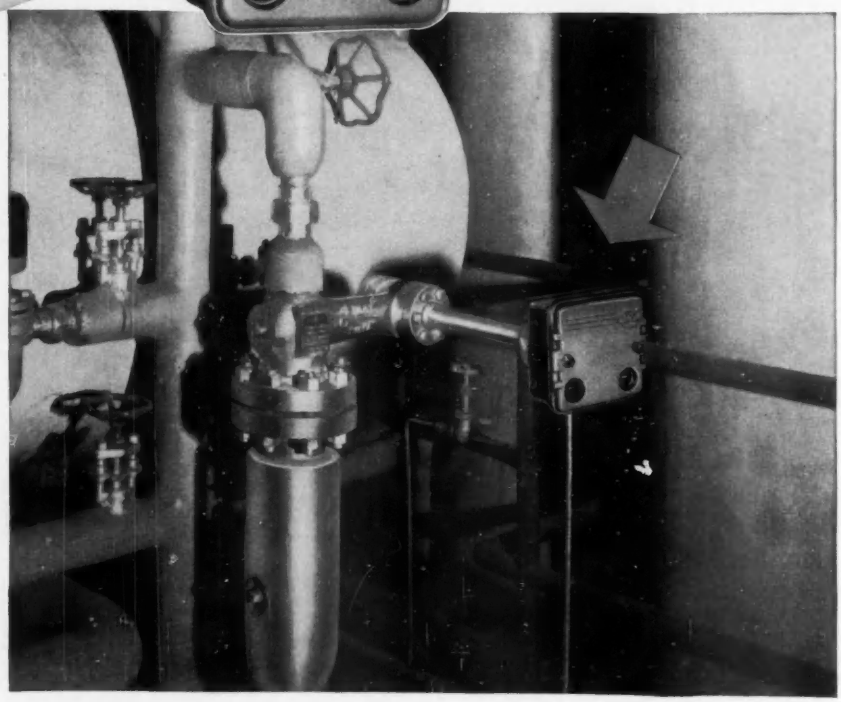
The Air Force will try to better its record of 126,000 ft this year. It is reported that present plans call for glide-testing North American's X-15 test vehicle (present thinking: return the manned satellite to earth by skipping it over the earth's atmosphere, like a rock is skipped over a pond). Then attempting a manned rocket-powered altitude test. Simulated manned flights in laboratories have already taken personnel up to 95 miles.

The race for space seems sure to have widespread implications throughout the control industry. For instance, tiny computers developed to guide rockets and space vehicles may also find application in machinery and process control systems. Rugged, all-environment components developed for space craft will give process and machinery control long-sought reliability.

When An External Cage Type Liquid Level Controller Is Indicated, Specify The . . .



BS&B Type 71-06, Series 2!



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1. **"Built In" Accuracy:** Engineered to control within close level tolerances.
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4. **Time Proven:** Utilized on heat exchangers, reboilers, deaerators, condenser hotwells and other similar applications in plants the world over.

For Complete Information On The BS&B Type 71-06, Series 2, Or Other BS&B Liquid Level Controllers, Contact Your BS&B Sales Engineer — or Write To . . .

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Control
ENGINEERING
FEBRUARY 1958

Distribute Russian Translations

Starkly clear stand the leads of Russian engineers in certain highly specialized technical developments, particularly missile production. Monitoring the developments for military intelligence by translating the key Russian literature is, of course, important. But even more important, it seems to us, is the need of English-speaking engineers to tap the fund of engineering knowledge accumulated by the Russians.

Control engineers fare pretty well here, for the truly significant literature on control technology is limited in volume and translated extensively. Some sources:

- Reviews and abstracts published in this magazine.
- Avtomatika i Telemekanika, translated by Consultants Bureau, Inc. ($185 per year)
- Elektrichestvo, translated by Pergamon Institute under the sponsorship of the National Science Foundation and in cooperation with MIT ($15 per year)
- Automation Express, an abstracting service surveying Russian literature on control systems and components, proposed by International Physics Index ($50 to $60 per year)

The U.S.A. is progressing toward making available translations of Russian publications in all areas of engineering. Government agencies, technical societies, universities, industrial firms, and commercial translation services translate some 40 of the 200 Russian technical and scientific journals that U.S.A. officials rate tops in quality and significance. This brisk acceleration in pace from a cold start four years ago is commendable. But the pace hides two critical weaknesses: much of the translation is duplicated, and little of it is freely available from a central source. The trouble is simply that each American group independently translates what it needs and then fails to contribute the knowledge to a clearing house because it does not want its technical interests identified. Industry is just as nearsighted in this regard as are the government agencies.

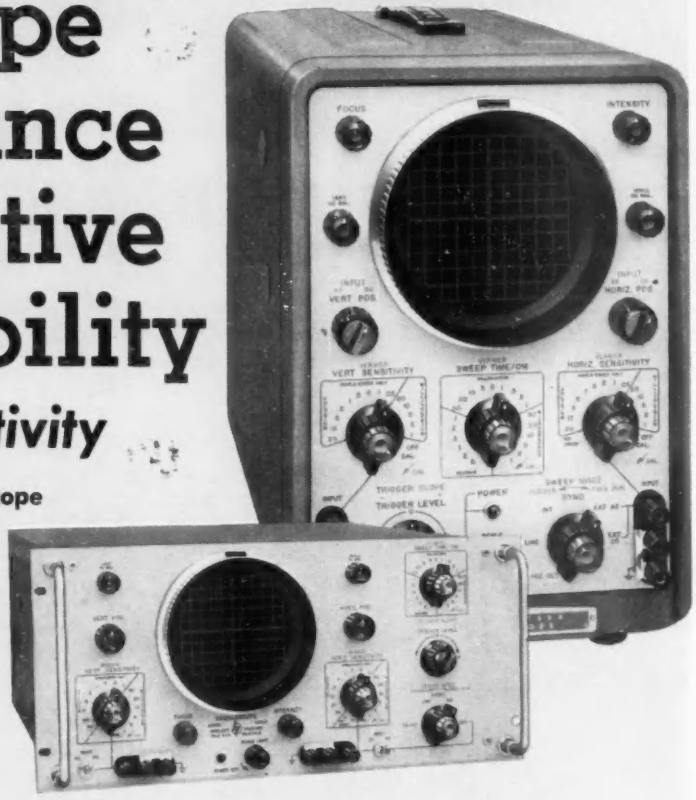
Our Washington News Bureau reports that the government is drawing plans for coordinating and distributing translations. For instance, the National Science Foundation wants to set up a clearing house for all translations of Russian scientific information, and the Commerce Dept. wants to do the same for engineering applications information. But unless the government can break the bottleneck of secrecy, clearing houses will have nothing to clear. Since identification of technical interests is the major deterrent, could a simple step – letting the contributor be anonymous – break the jam? We ought to try it before spending millions of dollars on the huge government translation program we will have if the jam cannot be broken.

THE EDITORS

Yours for $650

Big scope performance and positive dependability

...with 1 mv sensitivity



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Similar X and Y amplifiers
High stability, accuracy

We have been told, and we frankly believe, that the 130A is the best low frequency oscilloscope offered. Certainly, the best value.

But seeing is believing. Call your -*hp*- rep now, and ask him to bring over a 130A. Wring it out on your own problems, on your own bench.

See if you don't find it vastly simpler to use. Faster. More sure. Steady, dependable, versatile.

Note the "universal" automatic trigger arrangement which virtually eliminates resetting regardless of input. And the bright, rock-solid trace, generally without preamplification between scope and transducer.

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CABLE "HEWPACK" • DAVENPORT 5-4451
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SPECIFICATIONS 130A

Input Amplifiers: (Similar Vert. and Horiz. Amps.). Sensitivity 1 mv/cm to 50 v/cm; 14 calibrated ranges, 1-2-5-10 sequence plus continuous vernier. Pass band dc to 300 KC; ac or dc coupling. Balanced input on 1, 2, 5, 10 and 20 mv/cm ranges. Direct reading.

Sweep Range: 1 μsec/cm to 12.5 sec/cm. 21 sweeps, 1-2-5-10 sequence. Direct reading, 5% accuracy.

Triggering: Internal, line voltage or external 0.5 v or more. Pos. or neg. slope, +30 to −30 v trigger range.

Preset Trigger: Optimum setting for automatic stable triggering.

Amplitude Calibration: 1 KC square wave, 2% accuracy.

Price: -*hp*- 130A (cabinet) $650.00
-*hp*- 130BR (Rack Mt.) $650.00

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Which Rate Gyro to Use

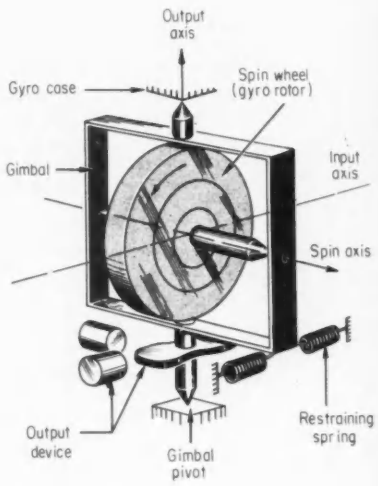


FIG. 1. Basic rate gyro construction

AIRCRAFT TYPE	GYRO CASE	GYRO GIMBAL	SUSPENSION	SPRING RESTRAINT	OUTPUT	DAMPING
Reciprocating engine	Unsealed	Unsealed	Two bearings	External spring	Microsyn or potentiometer	Undamped or air damped
Large turbojet aircraft (subsonic)	Depends on threshold level	Depends on case construction	Any	Any	Microsyn	Air damped or fluid damped (uncompensated)
High-performance fighters (supersonic)	Fluid filled, hermetically sealed (can be sub-miniature)	Sealed	Any	Any	Microsyn	Fluid damped (compensated)
Missiles	Fluid filled, hermetically sealed	Sealed	Two bearings or one bearing and cruciform	External or cruciform	Microsyn	Fluid damped (compensated)

HOWARD STERN, Convair, San Diego

In an airborne automatic control system, the rate gyro—a gyro with a single degree of freedom instead of two—provides an artificial means of increasing aircraft or missile damping (the vehicle's resistance to turning motion). Just how much damping is required depends on the aerodynamic design and shape of the vehicle. If the aircraft natural damping is large, little or no artificial damping is required; but if the aircraft is undamped, the gyro must provide virtually all the resistance. The smaller surfaces of high performance aircraft supply much less damping than the large wings and tails of transport aircraft.) The air density at which the craft flies influences damping, too: the higher the density the more natural resistance to turning is available.

As important as the amount of resistance is the response of artificial damping—how soon the rate gyro reacts to an input and how sensitive it is to even the smallest turning ratio. In general, the higher the natural frequency of the basic vehicle the better the gyro response must be. Large transport aircraft—with a period of oscillation of about 5 sec (0.2 cps)—can use a low-response gyro. But small fighter aircraft, which may have periods of oscillation of less than ½ sec (2 cps) require a gyro with a high natural frequency. And a higher natural frequency aircraft must have gyros with lower thresholds than a big, low-frequency aircraft.

Response time is further affected by how the flight control surfaces work. Surfaces move aircraft more efficiently when the ship is flying in higher dynamic pressures; therefore, in these higher pressures they must be brought into play sooner to avoid overshoot. If gyro thresholds are excessive, residual oscillations that cannot be removed by an automatic control system will develop. If gyro response is too slow, a basic servo loop instability can be produced, which results in a dynamically divergent oscillation.

Keeping these restrictions in mind, the designer of the control system can choose the best rate gyro design for a specific application by varying the gyro's components—they are listed, together with the advantages and disadvantages of their variations in the table on the next page—and by paying close attention to the performance and the environmental requirements of the application.

No basic rules for this selection, however, can be presented. For while it is desirable, for example,

DESCRIPTION OF RATE GYRO COMPONENTS

COMPONENTS		CHARACTERISTICS	ADVANTAGES	DISADVANTAGES
CASE	Unsealed	Can be any shape. Generally cast aluminum base with formed sheet metal cover.	Relatively inexpensive. Easy to maintain and repair gyro (by skilled instrument technicians).	Interior mechanisms subjected to corrosion, dust, etc. Lack of flotation permits bearings to brinnel increasing breakout forces and threshold. Gyro response for small inputs becomes very non-linear.
	Hermetically sealed—not fluid filled	Can be any shape with hermetically sealed cover.	Free from corrosion, dust, etc.	Subjected to same forces as non-sealed type.
	Hermetically sealed—fluid filled	Usually cylindrical shape with bellows to prevent cavitation of fluid under temperature change.	(1) Relieves load on bearings and reduces threshold deterioration. (2) Dampens effect of shock and vibration. (3) Dampens gimbal motion under input turning rates.	High cost; difficult to manufacture; requires specialized repair equipment.
GIMBAL	Sealed	Gimbal holds the high inertia wheel of the gyro (spin motor). Sealed gimbal is filled with helium to aid heat transfer from spin motor to gimbal case.	Sealed gimbals must always be used with fluid filled gyros to separate spin motor from fluid.	Expensive equipment; requires well trained technicians for repair.
	Non-sealed	Used with case which is not filled with fluid.	Inexpensive; comparatively easy to repair.	Cannot be used with fluid filled case.
SUSPENSION (Figure 2)	Gimbal suspended by bearings or jewel pivots at both ends	Must be restrained from motion by a separate spring device.	Provides good side load resistance and vibration resistance. Desirable when spring rate (full scale output) is very low and shock environment severe.	Additional bearing or pivot adds more friction than a torsion bar or cruciform. Higher thresholds are likely.
	Bearings or pivot on one end—torsion bar on other	Torsion bar serves as suspension and spring restraint.	Lower threshold value.	For low, full-scale outputs, soft torsion bar may not provide sufficient side load, shock, or vibration resistance.
	Torsion bars at both ends	No bearings used in suspension of gimbal.	Very low thresholds possible; threshold deterioration not likely to occur.	Cannot be used where high shocks or high vibrations are encountered (except where full-scale output is high). Difficult to mechanize because of thermal linear expansion.
SPRING RESTRAINT	Ordinary spring (coil, leaf or helical)	Used when gimbal is suspended by bearings at each end.	Provides any spring constant without affecting side load characteristics. Changes in full scale output, easy to create.	Extra part in gyro.
	Torsion bar	(See Figure 3a.)	Provides both gimbal restraint and gimbal suspension. Good choice in moderate shock environments.	Difficult to manufacture requiring tight quality control. Ratio of side load strength to torsional stiffness less than cruciform.
	Cruciform or quadra-lever	Under severe shock and vibration environment should be used in preference to torsion bars.	Provides both gimbal restraint and suspension. High ratio of side load strength to stiffness.	Bulkier than torsion bar. Difficult to manufacture in low stiffness configuration.
OUTPUT DEVICE	AC (variable inductance, reluctance, etc.) microsyn	Multiple winding starter. Rotor has non-symmetrical flux path.	No rubbing parts; no wear, no frictional restraint to increase gyro threshold. Infinite resolution.	Low level output (6 volts ac, low power) usually must be amplified. Must be demodulated to give dc signal.
	Potentiometer	Wire wound card with low friction wiper arm. Not used for threshold of .25 degrees/sec or lower. Not used if dynamic range is more than 200 to 1 (ratio of full-scale output to threshold value).	Can provide high level ac or dc output without amplification.	1. Increased gyro threshold. 2. Resolution limited by wire width. 3. Stands vibration poorly. Wiper arm oscillates rapidly around null point, shorting out the wires it crosses.
DAMPING MECHANISM	Air damped	Used where simple primitive damping is sufficient.	Simple construction.	Damping will vary with altitude and temperature.
	Fluid damped	3 types of fluid damping being used: (1) shear damping (2) piston damping (3) paddle wheel damping	Good characteristics at any specific temperature. Uses flotation fluid for damping purposes.	Requires elaborate compensator to adjust for change in fluid viscosity with temperature.
	Magnetically damped	Copper disc in magnetic field.	Small variations of damping with changes of temperature and other environments.	Heavy and bulky.

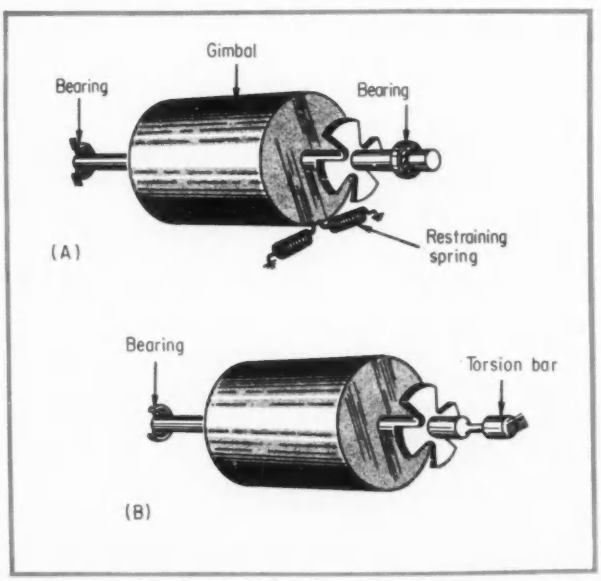
to specify as low a full scale as possible to avoid large null-type errors, it is often also desirable to have a high natural frequency. High natural frequencies have high spring rates and, therefore, high full-scale outputs. A compromise must be made by the designer using the equipment. To properly select a gyro, the systems engineer or designer must know the basic physics of a gyro and be aware of a number of practical obstacles.

The rate gyro is a relatively reliable piece of equipment on all propeller-driven aircraft. Performance requirements are not severe, nor is the environment particularly difficult to sustain. Vibration, greater here than on most jet-driven aircraft, affects only the gyro threshold, and the gyro threshold is not critical. Therefore, the least complicated rate gyro is best on such aircraft.

Large turbojet aircraft have almost as simple requirements for rate gyros as the reciprocating engine models. Since performance must be better from a threshold standpoint, potentiometer outputs should be avoided. If extremely small thresholds are required, and particularly if the gyros are subjected to high ambient vibration or to high jet engine noise levels, the filled, hermetically sealed rate gyro is recommended.

On high-performance fighter aircraft, the environmental level is relatively unsevere, but the performance required from the rate gyros is much greater. In general only fluid-filled gyros should be used. The smaller of these, sometimes called "sub-miniatures" (they measure about 1 in. in diameter by 2½ in. long), provide adequate performance and

FIG. 2. A—Gimbal supported by bearings at both ends. B—Gimbal supported by bearing at one end and torsion bar at the other.



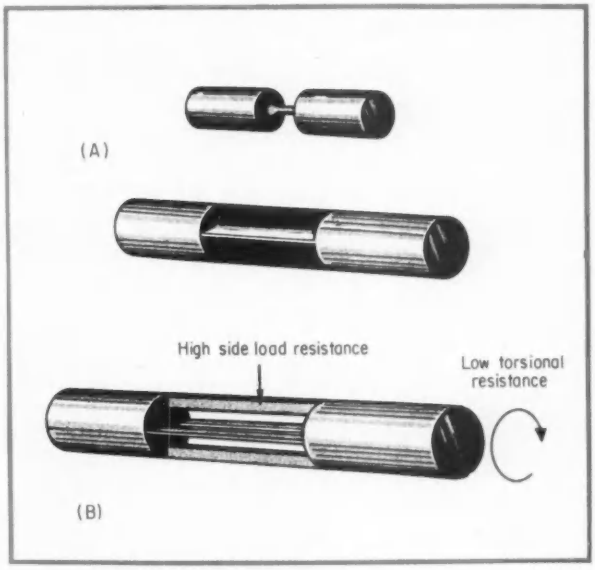


Fig. 3. A—Torsion bar. B—Types of cruciform springs.

environment resistance. Damping characteristics must be controlled over the complete temperature range. Potentiometers should not be used.

Missiles give a gyro its severest tests. They demand the very best performance and the most rugged of all rate gyros. The larger of the fluid-filled rate gyros is recommended whenever space permits. Here are some other missile critical points: Double torsion bar suspension should be examined carefully for side load and shock limitations. Damping ratios must be held over a wide temperature range. Potentiometers should be avoided. Ball-bearing suspension at both ends of the gimbal should be given a high priority. Cruciform suspension is probably superior to the usual torsion bar (particularly in gyros with a low-scale output rate). For full-scale deflection of less than 15 deg per sec, it would be wise to select a gimbal with ball-bearing suspension on both ends. If very large full-scale deflections are indicated, then any method of suspension will probably meet side-load requirements.

It is interesting that characteristics such as linearity and accuracy are not of prime importance in the null-seeking servo systems used in most automatic flight controls. More important are factors which are not determined by gyro construction, such as null voltage and null shift, sensitivity to vibration (output noise), cross coupling, etc. These factors are dependent upon careful design detail, design tolerances, manufacturing control, and quality control, and can be a problem if not monitored carefully. The primary danger is a false sense of security because of prior success with rate gyros on other aircraft configurations.

Newest Components for Reliable Switching:

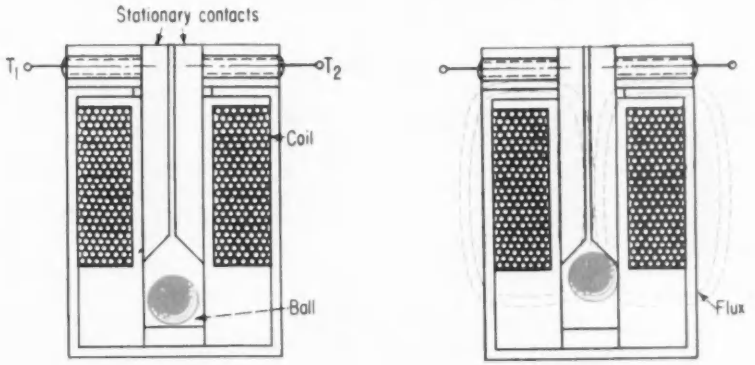
Multiple-Ball Relays

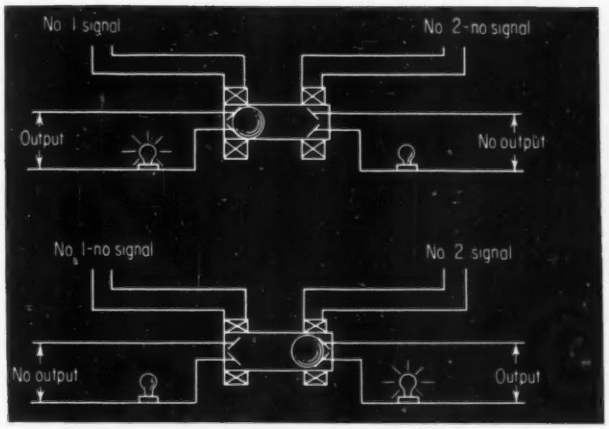
THE GIST: Because switching is the basic function in the majority of control systems, much effort is devoted to the development of reliable switch forms. The work has proceeded in two directions: toward improved electromechanical units and toward completely new components, notably magnetic amplifiers, transistors and proximity switches. Straddling both lines of approach is a recently introduced group of devices that may be classed as electromechanical in operation but that differ radically from conventional designs. The new devices use plated balls as movable contacts, making possible extremely simple construction and vastly increased contact life. While ball relays and limit switches are possibly of greatest immediate interest, detailed investigations have already shown the feasibility of applying the ball principle to mechanical rectifiers, potentiometers, function generators, logical elements, and proximity switches.

JOHN D. COONEY, Control Engineering

Because they are being used in greater numbers and in more severe environments, electromechanical contact-making devices are today the subject of much critical attention. In the light of this attention, the seriousness of historical faults such as bounce, chatter, arcing, and contact wear has worsened and prompted remedial action. One result is that conventional devices themselves have been vastly improved in areas such as arc suppression, contact materials, coil structures and armature mechanisms. A second outcome is the appearance of transistors, magnetic amplifiers and proximity devices especially designed for switching functions. In addition to these notable developments, there has recently been introduced by the Congress Controls Div. of Tann Corp., Detroit, a line of ball-armature components that provide much of the reliability advantage of static switching units while retaining the cost advantages of familiar electromechanical relays and limit switches.

The simplest form of ball-armature relay is shown in Figure 1. In the deenergized state, the ball of this normally open relay is resting at the bottom of the contact chamber. When current passes through the coil, flux lines thread the ball and pull it up tightly against the stationary contacts. This completes the circuit between terminals T_1 and T_2. Study of this uncomplicated design reveals some of the basic benefits of the ball-armature relay apart from its inherent simplicity. By choice of contact materials of proper relative hardness, the ball can be made to absorb most of the contact wear. And, since the ball presents an infinite number of contact surfaces, the effects of such wear are greatly





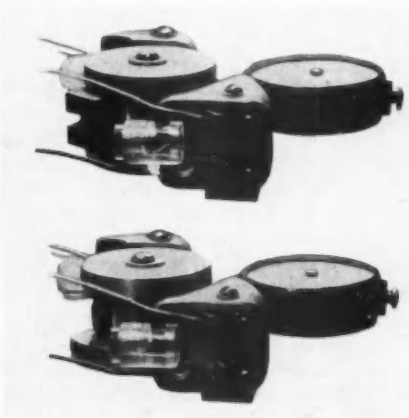
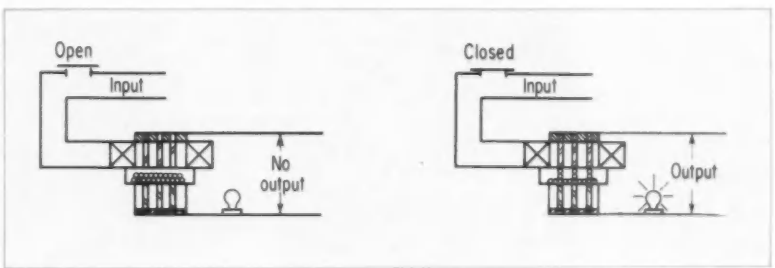


FIG. 1. Schematic of normally open ball-armature relay.

FIG. 2. Single-ball double-throw relay.

FIG. 3. Single-ball proximity switch on test.

FIG. 4. Multiple-ball relay unit with normally open contacts.



retarded. The ball armature represents little mass, so that fewer control ampere-turns are needed to provide fast, positive action.

An alternate design of single-ball relay employs an auxiliary plunger or armature inserted below the ball. The ball acts as the movable contact while the plunger serves to provide a very high hold-in force for certain applications. In a continuing test, a relay of this type cycling a 9-amp, 110-volt ac load has passed several million operations without failure. Control power for this load is about 0.02 watt.

A two-coil type of single-ball double-throw relay is shown in Figure 2. This form of construction is well suited for applications involving rapid cycling —a class of duty cycle that is extremely hard on conventional electromechanical relays. Latching and self-returning designs of single-ball double-throw relays are achieved by biasing the unit with permanent magnets. The latter are used as the energizing means in the single-ball proximity-type limit switch, Figure 3. Here the U-shaped magnet is mounted on a rotor. In this test model, the stationary contacts extend from each side of the ball case in a tongs-like configuration. As the magnet passes the external structure of these contacts, flux is conducted into the case, pulling the ball up and closing the circuit. Repeat accuracy of the proximity switch is excellent. The unit shown is energized consistently within plus or minus 0.001 in. of the design position.

Multiple-ball forms

In addition to Congress Controls, other organizations have conducted development work on single-

ball armature relays. Among these are Armour Research Foundation, Boeing Airplane Co. and the Teletype Corp. The efforts of Congress Controls, however, are unique in that extensive studies were made on a family of multiple-ball devices.

As the name implies, the latter type of construction employs a large number of smaller balls within the contact chamber. The multiple-ball unit differs radically from single-ball design in several other ways as well, as the normally open relay of Figure 4 illustrates. This consists of a short hollow cylinder of a dielectric material which is closed at both ends by plugs. These plugs are the stationary contacts and are connected to the output terminals of the relay. It is seen that the circuit can be closed by rearranging the balls to form a continuous mass extending from the upper contact to the bottom.

To get the necessary ball action, the upper contact is surrounded by a magnet coil. At this point, it is timely to explain the most important single factor contributing to a successful multiple-ball relay. This is the feature known as magnetic "focusing", which is accomplished by designing each stationary contact not as a solid permeable plug but as a group of permeable rods embedded in a nonpermeable structure. The rods in either contact are aligned axially with those of the other. Hence when the coil is energized, the flux lines extending between the stationary contacts are clustered in parallel groups rather than being uniformly distributed across the contact faces. This makes it possible to control the alignment of the balls into orderly strings as shown at the right of Figure 4. Without the orientation feature, the balls would shift in random bunches when the coil is energized, thus giving rise to highly variable resistances across the contacts. A permanent magnet is usually incorporated in the lower stationary contact to assure positive fast drop-out of the balls when the coil is deenergized. A cutaway view of the normally open relay is shown in Figure 5.

The normally closed configuration is depicted in Figure 6. Here, the permanent magnet is associated with the upper contact, biasing the relay so that ball strings are formed when the coil is deenergized. When the input circuit is closed, the bias is neutralized by the coil flux and the balls drop to break contact. The rapid switching and long service life characteristics of the multiple-ball relay make it adaptable as a mechanical half-wave rectifier, Figure 7. The unit used here is the normally closed type with permanent-magnet bias. The ac input sets up coil flux that alternately aids and bucks the bias flux. The output of this rectifier is a square wave. Units have operated satisfactorily on 60-cycle inputs and, with biasing magnets in the lower contacts, at frequencies up to several hundred cps.

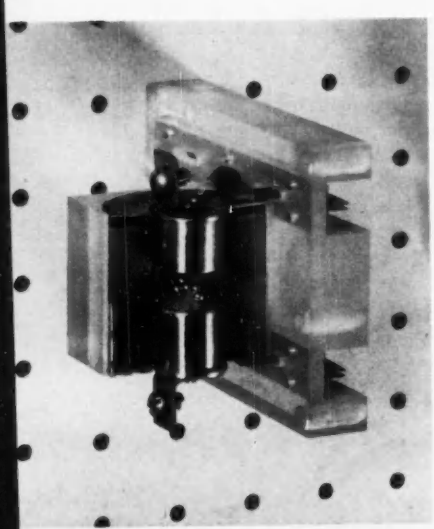
Multiple-ball switches

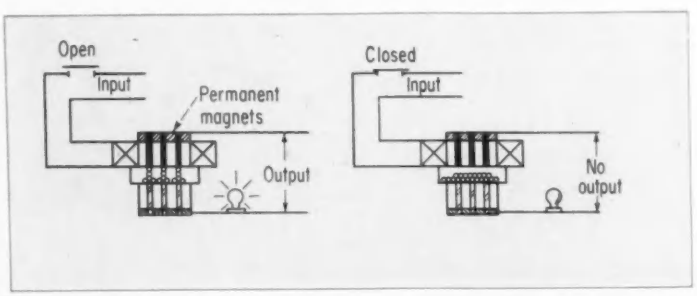
The multiple-ball construction has been carried over to a group of devices other than relays. These devices include linear and nonlinear potentiometers and resistors, limit switches, zero-speed switches, and transducers. A proximity-type limit switch is shown

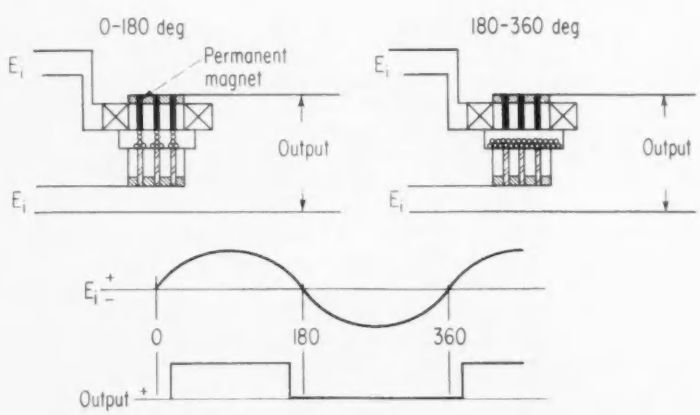
FIG. 5. Cross sectional view of multiple-ball relay.

FIG. 6. Multiple-ball unit with normally closed contacts.

FIG. 7. Normally open relay in mechanical-rectifier application.







in Figure 8. Rods of Alnico V bias the upper contact so that the load circuit is normally closed. The permanent magnet carried by the mechanical element being controlled is positioned so that it tends to repel the contact magnets. Thus as the moving magnet approaches the switch, the bias is overcome and the balls drop to open the circuit.

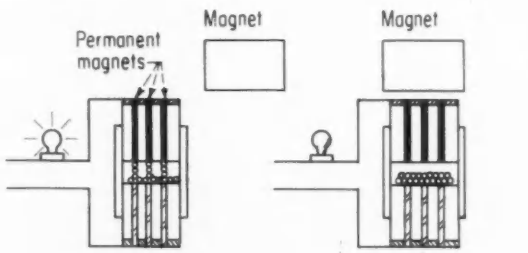
The snap-action limit switch, Figure 9, is actuated by mechanical contact and employs a "magnetic-toggle" arrangement. The switch plunger is attached to a driver consisting of a four-pole ring magnet. Two additional ring magnets located within the first are used to rotate the movable contact structure. At rest, the magnet alignment is as shown in section B-B, so that the driver magnet and the upper driven magnet are locked together. When the limit-switch plunger is depressed, the driver magnet is brought into proximity with the lower ring magnet, which is 90 deg out of phase with the upper magnet. The resulting alignment, section C-C, is unstable, so that the driven magnet rotates 90 deg. When the plunger is released, the magnet alignment is again reversed and the contact rotor snaps back to its original position.

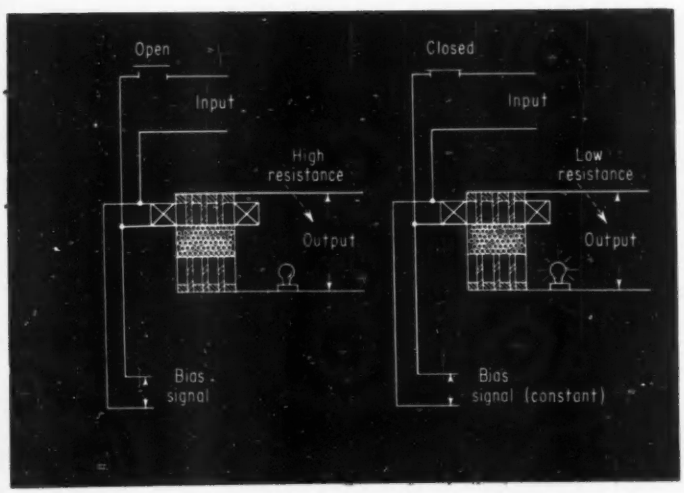
A detail of the contact rotor, section A-A, shows the at-rest relationship between movable and stationary contacts. The movable contact consists of a cavity in the rotor which is partially filled with balls. When the movable contact is rotated between the stationary contacts, Alnico V rods in the latter set up ball strings to complete the load circuit.

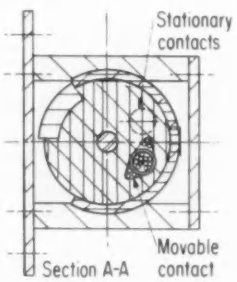
The resistor-potentiometer applications of the multiple-ball principle may be explained by examining a surge-limiting or "step-starting" relay, Figure 10. In this case, the contact chamber is filled with balls of known resistivity so that the circuit between stationary contacts is bridged at all times. When the coil is energized rigid ball strings are formed, reducing the contact resistance to a low value.

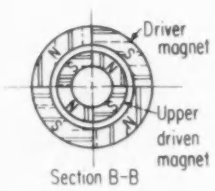
The filled ball cavity employed in the surge-limiting relay is the basis of the ball potentiometer. Referring back to Figure 9, it will be noted that the rotary construction (without, of course, the snap-action feature) makes it possible to slide the movable contact gradually between the stationary contacts. If the cavity is filled with balls and the rotor moved slowly, the resistance will be progressively reduced from maximum to a low value. This is because the number of ball chains increases as the permanent-magnet rods come into play. The greatest number of ball chains is available to share the load current when the full areas of both movable and stationary contacts are in correspondence.

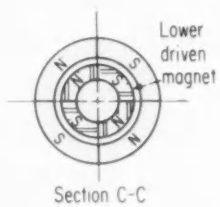
Since there is little sliding friction between the stationary contacts and the balls in the cavity, wear in this type of potentiometer is much less than in the conventional slide-wire unit. A variety of resistance ranges can be provided by the use of balls coated with resistive material such as Nichrome alloys. An additional advantage is that the ball cavity can be shaped to provide any type of resistance vs. position characteristics. Such shaping also makes possible the design of function generators. Note that the ball cavity in Figure 9 is not only











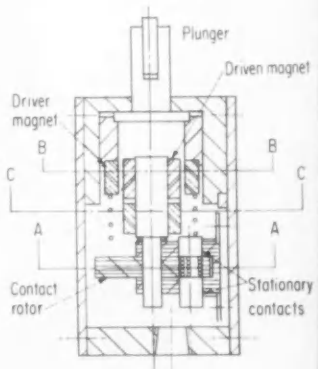


FIG. 8. Proximity-type multiple-ball limit switch.

FIG. 9. Mechanically tripped snap-action limit switch.

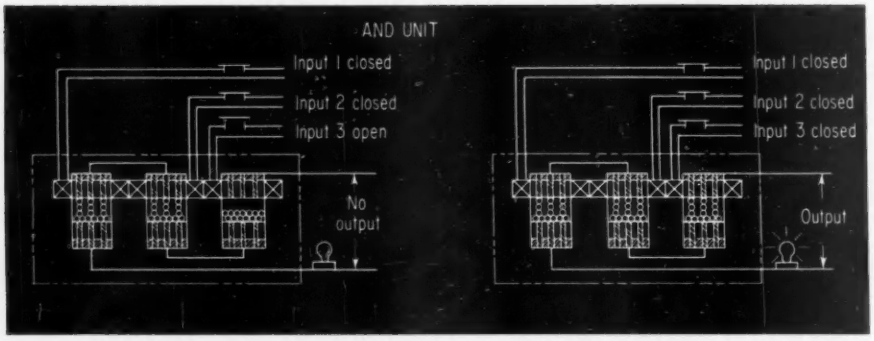
FIG. 10. Surge-limiting relay offers variable resistance to load currents.

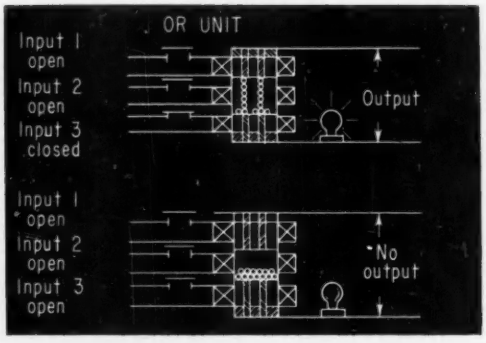
MULTIPLE-BALL LOGICAL UNITS

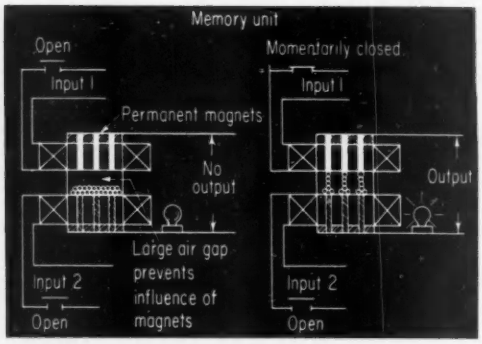
In one outstanding respect, the multiple-ball design is similar to the magnetic amplifier used in the switching mode. Like the latter, the multiple-ball unit can be made to react to a combination of various input signals. This feature is accomplished by making use of the effects of magnetic buck, boost and bias to establish various patterns of operation. Such control flexibility makes it possible for multiple-ball devices to function as logical elements in the fashion of the static switching devices now receiving so much attention. One advantage of the ball devices in such service is their ability to handle load currents of considerable magnitude.

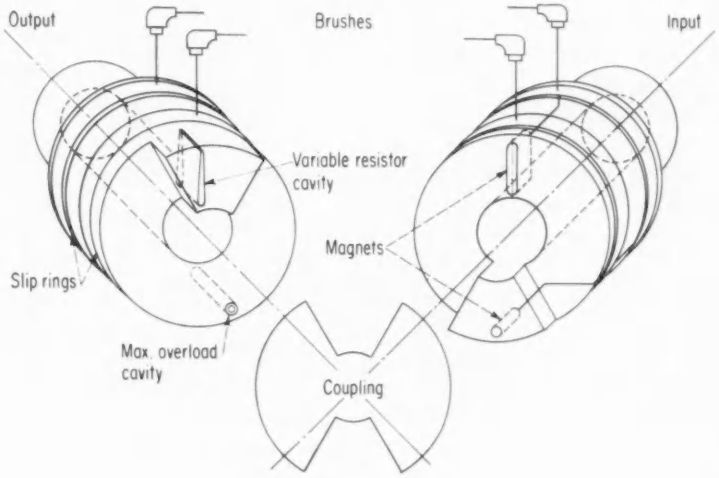
The five major logical functions are AND, OR, NOT, memory and time-delay. The NOT unit is simply the normally closed relay described elsewhere in this article. With such a relay an output is produced when there is not an input. The three-element AND unit illustrated herewith consists of three normally open multiple-ball relays with the stationary contacts connected in series. Only when input 1 and input 2 and input 3 are present is the output circuit complete. The OR unit shown is a normally open relay with three separate control coils. Energizing any one of the coils is sufficient to make the load contacts.

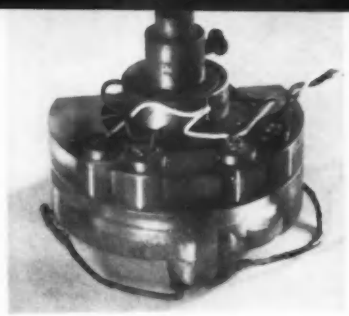
The latching or memory relay employs two control coils, one for make and one for break. The upper contact contains permanent magnet material with sufficient field strength to hold the balls after they have been aligned, but not enough to pull them from the bottom of the contact chamber. Hence, momentarily closing input 1 has the effect of energizing the upper coil and closing the circuit. This closure is then maintained even after pushbutton No. 1 has been released and until pushbutton No. 2 is depressed to overcome the permanent-magnet bias. Some measure of time-delay action is feasible also through the use of balls made of ferromagnetic material that saturates slowly. Thus, when the control coil is excited there is some time lag before the balls are aligned and the load circuit closed. The range of time delay is limited by the selection of materials available for the balls. Work is proceeding on attempts to design practical ball relays having adjustable time delay action.











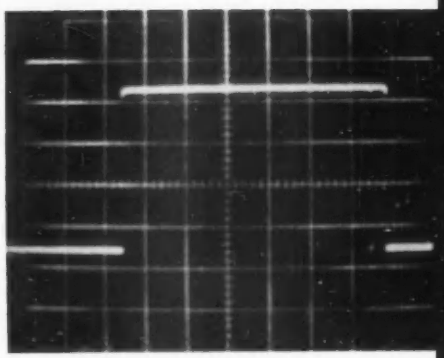


FIG. 11. Multiple-ball coupling produces signal voltage proportional to torque transmitted.

FIG. 12. Torque transducer used for power-steering control.

FIG. 13. Oscillogram of contact action in multiple-ball relay.

shaped to provide a continuous resistance change of some desired slope, but also is compartmented. Since coatings of two different resistivities are used on the balls in each compartment, an abrupt function is superimposed on the continuous slope.

The torque-sensitive transducer in Figure 11 employs a variable resistor cavity as a means of measuring deflection. This torque sensor is actually a shaft coupling with two structural sections bonded together through a rubber piece. When the coupling is transmitting no load, the permanent magnet is fully aligned with the variable resistor cavity and the resistance through the contacts is low. As load is added at the output shaft, the rubber bond allows the two sections of the coupling to move with respect to one another. The amount and direction of this change depends on the magnitude and direction of the load torque. Thus the contact resistance gradually increases in proportion to load torque. A current-sensitive instrument connected across the contacts yields a direct measurement of torque.

An additional cavity and magnet are incorporated in the coupling to provide positive indication of overload. Within the normal torque range, this magnet and cavity are out of contact. When the safe deflection of the coupling is exceeded, the magnet moves over the cavity, completing a circuit through the two outermost brushes to some type of warning or protective apparatus. Figure 12 shows a multiple-ball torque-sensitive transducer designed for a power-steering servo. The ball cavity and one stationary contact are at the bottom and four additional stationary contacts are at the top. The two outside contacts are for indicating over-deflection. The inside contacts provide signals depending on the direction and the amount of rotation of the wheel.

Test results

To amass a complete set of operating data for ball-armature devices, a continuous test program is under way. One of the biggest areas of investigation is the plating materials used for the balls. The prime concern here is to obtain minimum contact resistance. Of the various plating materials tried, silver cadmium oxide, rhodium, palladium, and platinum show the most promise. Silver cadmium oxide plating is the general-purpose standard.

Two other variables of importance are the number of balls used in the relay cavity and the diameter of these balls. As a result of cut and try studies, the optimum number of balls has been standardized at 17 and their diameter at 0.2532 in. Again, these specifications apply to general-purpose relays only.

At rated coil voltage, contact resistance is surprisingly constant. In a test run to measure the contact resistance of a 17-ball relay, the relay was operated 10 times at each of six different coil voltages. Resistance was lowest at the 50-volt rating, the average noted being 1.73 milliohms. Higher readings were obtained when lower voltages were applied to the control coil and at 30 volts above rating. Figure 13 is an oscillogram showing the operating speed of a 17-ball relay. The relay was totally enclosed feeding a dc load. The oscillograph was connected across the load resistor so that the ordinate of the oscillogram represents the drop across that resistor. At make, this drop rises abruptly from zero, remains level, then drops again at break. The abscissa is calibrated at 20 millisec per cm.

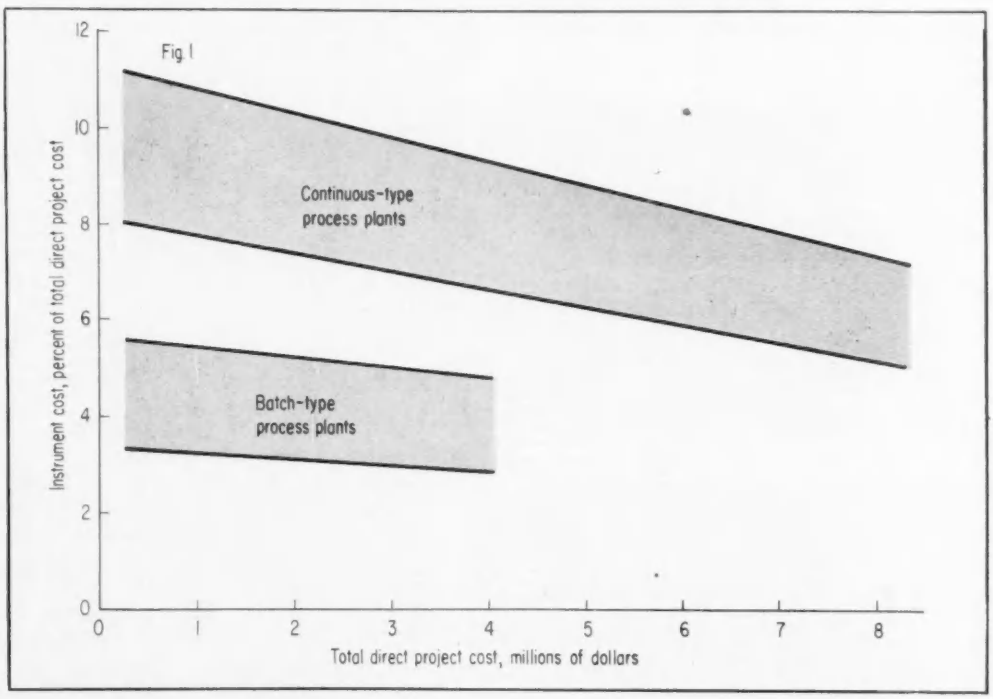
Acknowledgment:
The devices described in this article were developed by Stanford R. Ovshinsky of Congress Controls Div.

Three ways to estimate

INSTRUMENTATION COSTS OF PROCESS PLANTS

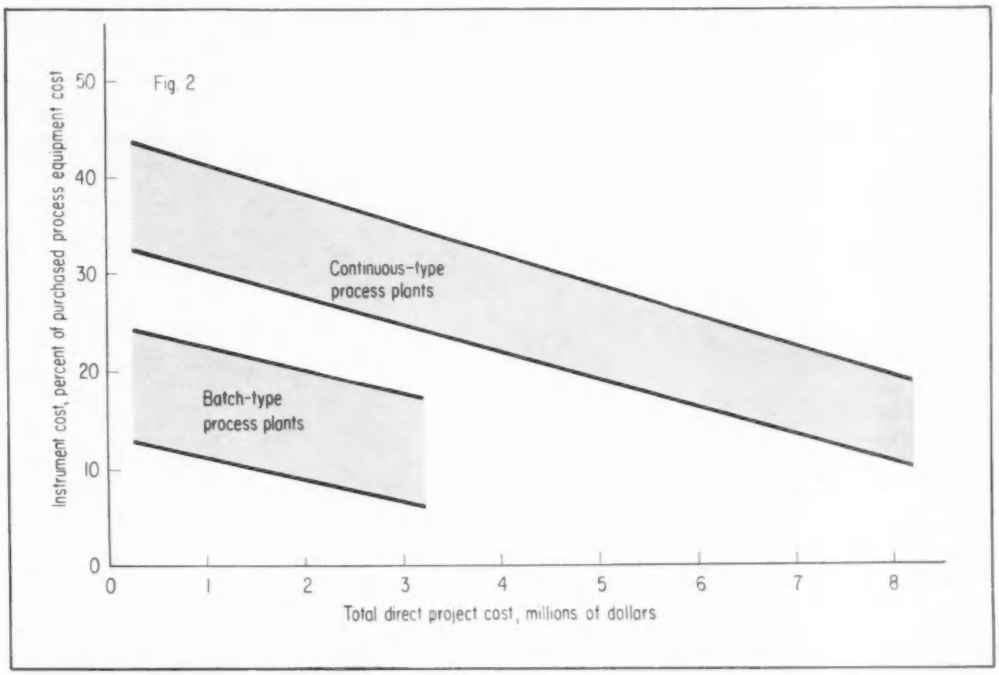
Instrument and control costs are a significant portion of the total investment in process plants, and estimates of such costs must be made with increasing accuracy throughout the progress of an engineering project. Three instrumentation cost-estimating methods of varying accuracy have been developed. They are presented here together with suggested figures to use, and a detailed instrumentation cost estimate—for a distillation column—based on the most accurate of the three methods.

JOHN W. BERNARD, Dow Chemical Co.



1. Estimating based on total direct project cost

The first estimating method uses the graph shown in Figure 1. It is of most value early in the course of the project, when it can give the approximate range of the total instrument costs. Here, the direct cost for instrumentation is estimated as a percentage of the total direct project cost. This is the simplest of the three methods. It is also probably the least accurate: for instance, the cost of a warehouse will raise the total direct project cost, but will not affect instrumentation costs at all.



2. Estimating based on major process equipment cost

The second method employs a graph of direct instrument cost as a percentage of purchased process equipment cost, vs. total direct project cost, Figure 2. This method is of greatest value in preparing preliminary economic evaluations. Here the cost of the major process equipment is determined, and this figure becomes a more realistic base for estimating the instrument costs. Note that the percentage to use varies with the total project cost.

The data in Figures 1 and 2 was obtained from a Dow Chemical Co. instrument cost survey of many production-size chemical process plants which have, in most cases, open-type construction with a minimum amount of buildings. None of the estimates includes engineering fees and overhead, or contractor's overhead and profit. These add up to approximately 25 or 30 percent of the total direct cost. The two graphs show that batch-type process plants have smaller percentage of instrumentation costs than do continuous-type plants. This seems reasonable in view of the fact that the instrumentation for batch operations is normally not as complex as that required for continuous operation. Also, production-size batch equipment is usually quite large in comparison to continuous-type equipment, and represents a larger portion of the plant costs.

3. Estimating based on installed cost of typical instrument systems

Once a project has been studied long enough to determine the instrumentation systems needed to control the plant, a cost estimate–based on the *installed* costs of typical instrument systems—may be prepared fairly quickly and more accurately than the two previous methods. This estimate relies on detailed cost data such as has been accumulated in Table I. The upper left portion of this table contains the installed cost data for systems using:

- ▶a pneumatic transducer or thermocouple transmitting to an instrument at a remote panel
- ▶a controller having proportional and reset actions
- ▶a valve of 1-in. diam made of cast iron, without positioner

The rest of Table I contains data for such additional features as: installed costs for rate action, pneumatic set-point in cascaded systems, valve positioner, larger control valves, alloy or steel valves, air dryers, and the requirements for compressed air, electric power, and floorspace for instrument panels. For an example of how additional costs are added to basic costs, assume a flow recording controlling system (FRC-2 in the estimate worked out in Table III for the plant shown in Figure 3) with a 3-in. alloy control valve:

• FRC system with 1-in. cast-iron valve, from Table I	$1,656
• Subtract for 1-in. cast-iron valve	−240
• Add for 3-in. alloy valve ($480 plus 2 x $320)	+1,120
Total	$2,536

Such instruments as stream analyzers and program-

TABLE I. INSTALLED COSTS OF INSTRUMENT ITEMS AND SYSTEMS

Instrument Item or system	Total*** Installed Cost, $	Minimum Panel Standard	Floorspace Miniature	Air, SCFM	Power, Watts
Alarms	$120 plus switching items cost	½	½	—	10
Ammeter system	80	3	3	—	—
FI, flow indicator	216	—	—	—	—
FG, flow gauge glass	80	—	—	—	—
FR, flow recording, system	896	12	3	½	2
FRC, flow recording controller, system*	1656	12	3	1	2
FS, flow switch	160	—	—	—	—
LC, level control, system*	616	—	—	½	—
LG, level gauge glass	80	—	—	—	—
LI, level indicator, system	536	3	3	½	—
LR, level recorder, system	800	12	3	½	2
LRC, level recording controller, system*	1560	12	3	1	2
LS, level switch	192	—	—	—	—
pHI, pH indicator, system	1016	5	5	—	25
pHR, pH recorder, system	2184	17	8	—	75
pHRC, pH recording controller, system*	3016	17	8	1	75
PC, pressure controller	240	—	—	—	—
PI, pressure indicator (std.)	32	—	—	—	—
PI pressure indicator (chem. type)	128	—	—	—	—
PR, pressure recorder, system	608	12	3	½	2
PRC, pressure recording controller, system*	1368	12	3	1	2
PS, pressure switch (standard)	40	—	—	—	—
PS, pressure switch (special)	160	—	—	—	—
SI, speed indicator system	344	3	3	—	—
TC, temperature controller	200	—	—	—	—
TI, temperature indicator	56	—	—	—	—
TI, temperature indicator, multipoint	2600	12	12	—	50
TIS, temperature indicating switch, system**	520	5	5	—	100
TR, temperature recorder, single point	1200	12	3	—	50
TR, temperature recorder, multipoint	2768	12	12	—	75
TRC, temperature recording controller, system*	1872	12	3	½	50
ADD FOR:					
Valve-pneumatic (cast iron)	$240 + $160/in. over 1 in.	—	—	—	—
Valve-pneumatic (steel)	$240 + $240/in. over 1 in.	—	—	—	—
Valve-pneumatic (alloy)	$480 + $320/in. over 1 in.	—	—	—	—
Valve positioner	160	—	—	½	—
Valve-solenoid	32	—	—	—	70
Air drier	25/SCFM	—	—	—	30/SCFM
Rate action	50	—	—	—	—
Pneumatic set-point	170	—	—	—	—

* With 1-in. cast-iron control valve with pneumatic actuator, no positioner
** With solenoid valve
*** Based on instrument costs in summer of 1957 multiplied by 160 percent factor (see Table II)

TABLE II.
DERIVATION OF INSTRUMENT INSTALLATION COSTS

	Labor, Percent	Material, Percent	Total, Percent
Purchase & Mounting	15	100	115
Instrument piping	17	5	22
Instrument wiring	17	4.5	21.5
Sandblast & paint	1	0.5	1.5
Totals	50	110	160

Add 60 percent over purchase price

The installed-cost figures in Table I are based on 160 percent of the purchase price of the instrument items. Table II shows the derivation of this factor. The costs and percentages shown in Tables I and II will, of course, vary from company to company, depending on local situations and accounting methods and from time to time on the changing costs of instruments and labor.

ers are not included in Table I. Their cost should be added to the estimate, and their approximate purchase price multiplied by 160 percent to obtain installed cost. Also, costs for panel floorspace, control house, air compressor for pneumatic instruments, and special features are not included and should be added separately.

Estimating floorspace requirements

The minimum panel floorspace requirements given in Table I provide an estimate of the control room area. These figures are based on the use of 2-ft-wide by 7½-ft-high panel sections with an average density of instruments, so that space requirements can be compared. A full graphic panel using miniature instruments would probably require the same space as a nongraphic standard-instrument panel.

The minimum panel floorspace of 2-ft-wide section is assumed to be 30 sq ft; this allows 10 ft in front of the panel and 5 ft in back. It does not include space for an operator's desk or any other items that might be desired in the panel area. The normal density (instruments per panel section) is taken as:

- 2½ for standard-case panel instruments (12 sq ft)
- six for small-case instruments (5 sq ft)
- 10 for miniature-case instruments (3 sq ft)

Dividing the floorspace per section (30 sq ft) by the density results in the equivalent floorspace per instrument. These figures are shown in parentheses above. Panel length can be computed by dividing the total estimated floorspace from Table I by 30 sq ft to obtain the number of 2-ft panel sections needed. The air requirements are based on an average of ½ scfm per instrument item that uses air, and the electrical power requirements are based on typical listings in manufacturers' literature.

$12,176: Installed instrumentation cost estimate for this distillation system

Keeping costs up to date.

The most serious errors in the type of instrumentation cost estimate carried out in Figure 3 and Table III come as a result of in complete instrument lists. This is usually caused by faulty information at the time the estimate is made, or by a change in scope of the project. But a cost error can occur even when the estimate does include all instrument items, if future changes in prices are not anticipated for instruments to be purchased at a later date.

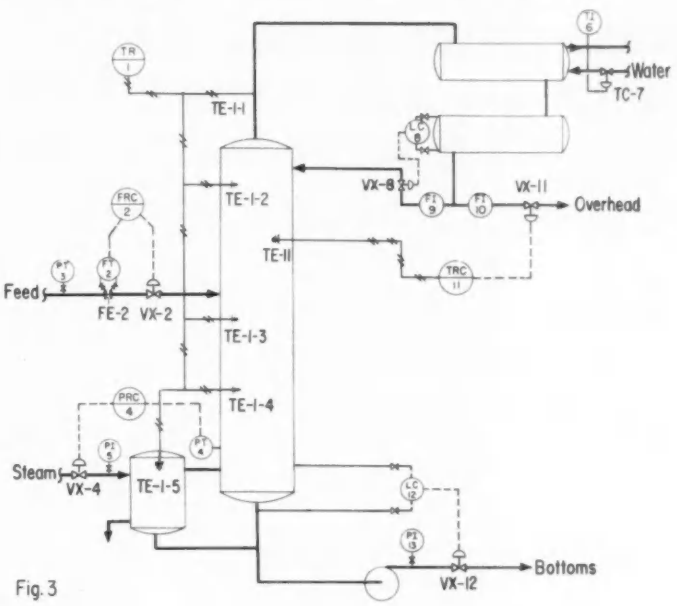


Fig. 3

TABLE III. ESTIMATE FOR DISTILLATION COLUMN

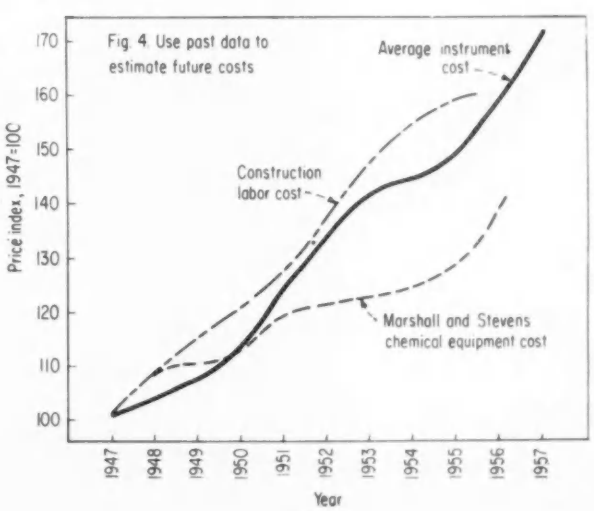
Instrument item or system	Installed cost	Minimum panel floorspace Standard	Minimum panel floorspace Miniature	Air, SCFM	Power, Watts
TR-1 (multi-point)	$2,768	12	12	—	75
FRC-2 system	2,536*	12	3	1.0	2
PI-3 (chemical)	128	—	—	—	—
PRC-4 system	1,848*	12	3	1.0	2
PI-5	32	—	—	—	—
TI-6	56	—	—	—	—
TC-7	200	—	—	—	—
LC-8 system	1,176*	—	—	0.5	—
FI-9	216	—	—	—	—
FI-10	216	—	—	—	—
TRC-11 system	2,112*	12	3	0.5	50
LC-12 system	856	—	—	0.5	—
PI-13	32	—	—	—	—
Total	$12,176	48 ft²	21 ft²	3.5 SCFM	129 Watts

*Includes additional valve cost shown below

Valve	Size	Material	Installed cost over 1-inch valve
VX-2	3 in.	Alloy	(480-240) + (2 × 320) = $880
VX-4	4 in.	Cast Iron	(3 × 160) = 480
VX-8	2 in.	Alloy	(480-240) + (1 × 320) = 560
VX-11	1/2 in.	Alloy	(480-240) = 240
VX-12	2 in.	Steel	(1 × 240) = 240

Panel sections: Standard = 48 ft²/30 ft² per section = 2 sections
Miniature = 48 ft²/30 ft² per section = 1 section

Figure 4 shows how prices of instruments, chemical process equipment, and construction labor have risen since 1947. This information can be used to extrapolate future costs into present-day estimates. The curve for instrument costs is based on the average prices of typical instruments and valves manufactured by several of the larger instrument companies; the curve for process equipment cost is based on the "Marshall and Stevens Annual Indexes of Comparative Equipment Costs, 1913 to 1956" as published in *Chemical Engineering*, March 1956; and the curve for labor cost is based on data taken from the "Statistical Abstract of the U. S., 1956."



COMBINED CLOSED- AND OPEN-LOOP PRESENTATION

EDMUND G. TRUNK, Servo Corp. of America

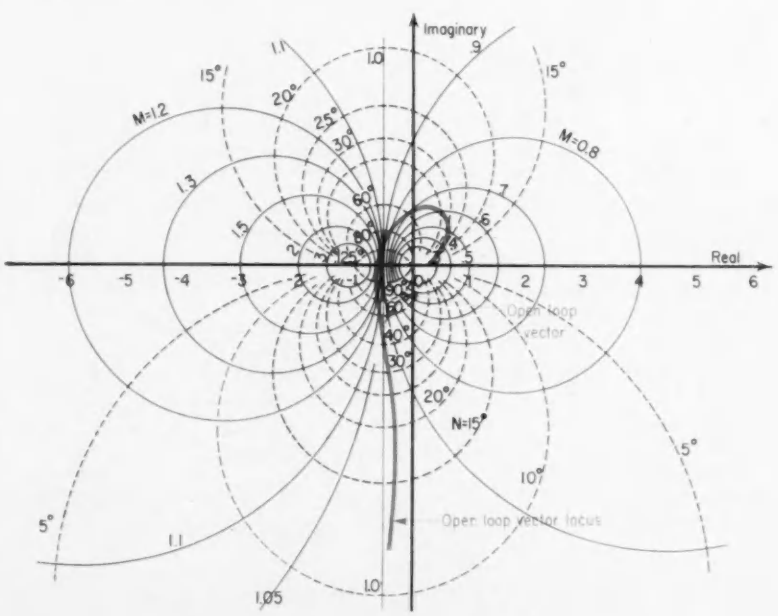
Servo dynamic performance is most widely tested and presented as a frequency response. Open-loop frequency response data is reported on a Nyquist diagram (a plot of the complex vector at each test frequency) or on a Bode diagram (phase shift and logarithm of amplitude ratio vs. logarithm of frequency). But to obtain open-loop frequency response directly the control loop must be opened. Because nearly all feedback control systems contain a motor or some other element that integrates system unbalance, any source of unbalance–ac pickup, load torque, tube unbalance, amplifier unbalance, or motor unbalance–causes a continual drift in the system output when the loop is opened. It is difficult to sort out the sinusoidal component of the output when it is superimposed on a steady drift. And the output can drift to a limit.

Solutions?

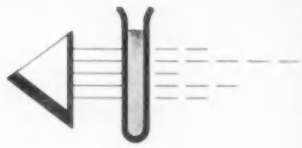
- Inject an adjustable signal and balance the drift.
- Measure output rate, which suppresses the drift component. Divide the output rate amplitude by the rate measuring scale factor and subtract 90 deg from the phase shift between input and output. (But the output will still drift to a limit because the drift is not balanced.)
- Measure the closed-loop frequency response and plot it on specially prepared charts from which the open-loop response can be scaled. This data file describes one such method which is very satisfactory when the feedback contains no dynamic elements.

Servo analyzers are available from several manufacturers of electronic test equipment. One generates a sinusoidal test input at variable frequencies and a synchronized saw-tooth sweep voltage at an adjustable phase shift from the test input. The test operator measures the output amplitude on an oscilloscope. Then, after he adjusts the oscilloscope display to a reference pattern, he reads from the phase dial on the servo analyzer the phase shift between the input and output signals. He makes only one calculation—dividing the measured output amplitude by the input amplitude (may be constant over the frequency range tested).

On the *M*, ratio of closed-loop output to input, and *N*, phase shift between them, circles of the special paper shown in the figure, the operator plots the test data. He may read the open-loop amplitude ratio with a ruler and the open-loop phase shift with a protractor from the resulting vector locus (one vector is shown). Because this special paper combines the closed- and open-loop data, the design and application engineer using it may switch from one to the other, as required by the nature of his problem. The reader may construct the chart paper by referring to pages 177 through 180 of Brown and Campbell, *Principles of Servomechanisms*, John Wiley & Sons. Or he may obtain complimentary copies of it, as well as tables for recording frequency response data and charts for plotting Bode and Nyquist diagrams, from Servo Corp. of America.



Special chart paper combines closed-loop response plot with Nyquist diagram of open-loop response for systems with no dynamic elements in the feedback path. M circles are scales of constant closed-loop amplitude ratio, N circles scales of constant closed-loop phase shift between input and output.



Analyzing and Controlling Products From COLOR Measurements

Color plays a critical role in the manufacture of pigments, paints, dyestuffs, foods, plastics, synthetic fibers, coated fabrics, pharmaceuticals, and many other industrial and consumer products. Some products are manufactured in batch-type processes and their color can be controlled by periodically checking grab samples on laboratory-type colorimeters. Others, continuously processed, have generated interest in the plant techniques and instruments for rapid and continuous color measurement. Colorimeters have already been applied to some continuous processes, but progress has been hampered by the complexity of color science and the difficulty of making accurate and reproducible color measurements.

Glasser describes the basics of color measurement, explains the operation of laboratory colorimeters for product investigations and control and plant-type colorimeters for abbreviated color measurements, and details applications of both. He also covers the preparation of product samples.

LEO G. GLASSER
Engineering Research Laboratory
E. I. du Pont de Nemours & Co., Inc.

A color-specification system is a system of numbers that represents colors so precisely that two observers, even at widely separated locations, will invariably get the same color from the same calculations. Color control in the past has generally been based on visual judgments of color differences. Today's colorimeters for quality control offer several advantages over this method. For one, they yield quantitative numerical readings so that color deviations can be correlated with processing variables. The result is improved processing technique.

Colorimeter readings in the form of numbers also facilitate communication between sales offices and plants: numerical specification of a color agreed on in the plant or with a customer now can be substituted for material standards, which are subject to various forms of degradation.

Batch processing time is also saved by using colorimeters. Although it is true that a single color measurement takes just as long or longer than a visual color judgment, the advantage is in the reduced number of measurements needed to adjust the product to a specified color. By means of quantitative numerical readings, a correction may well be calculated in one large step.

In-process materials also respond exceedingly well to colorimeters even though these instruments have been traditionally applied to finished products. In-process color measurements show up process deviations early enough so that steps can be taken, manually or automatically, to correct color errors in the product. This advancement of the color-control point is not always, of course, straightforward. The material to be inspected at the upstream control point seldom has exactly the color of the final product. The need, therefore, is for correlations that will assure prediction of the final-product color from the in-process color. Examples of such in-process colorimetry where suitable correlations have been developed include:

- dye solutions to predict fabric or paper appearance
- wet paint color to predict dry paint color
- pigment slurries for several uses

In-process control of color offers other advantages. The material to be controlled in some cases can be found at high concentration, hence with a brighter and more easily detected color, early in the process. If the subsequent handling and blending steps can be relied on, enhanced accuracy of color control can be achieved.

Spectral absorption

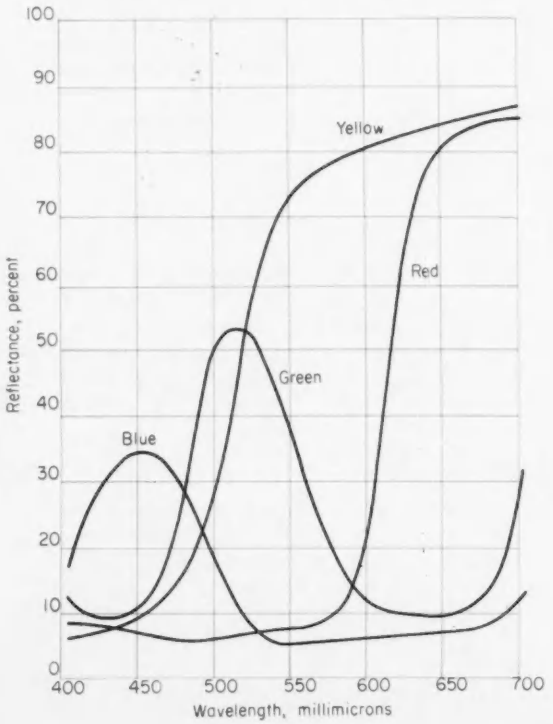
Spectral absorption curves, such as those shown in Figure 1, give the physical specifications of a color. They represent a material's absorption in terms of percentage of transmitted or reflected light at all wavelengths in the visible region of 400 to

700 millimicrons. Equal-intensity light at all visible wavelengths would appear white.

Colors are the result of the eye's integration of spectrum colors, which range from the short wavelengths at violet, up through blue, blue-green, yellow, and orange, to long wavelengths of red. When a material preferentially absorbs violet and blue wavelengths the resulting color is yellow. When the absorption band extends toward the longer wavelengths the color is orange, and if it extends even further, the result is red. Green occurs when the longer and shortest wavelengths are absorbed, blue when all but the wavelengths near the short end of the spectrum are absorbed.

The use of spectra for describing color, although basic, is too difficult for universal use—and simpler systems generally are used for relating physical specifications of color to visual impressions. Practical light sources emit an amount of energy that varies with wavelength, and this must be taken into account in estimating color. Standard practice in the United States for viewing colored materials is to use an artifical source having an energy distribution corresponding to daylight known as Illuminant C of the International Commission on Illumination. In describing a color, this illumination source, together with the illumination angle and the viewing angle, must be specified. One type of illuminating and viewing condition is 45 deg—0 deg; for reflection colorimetry some of the tristimulus filter colorimeters, the most common color measuring instruments, illuminate at 45 deg to the sample surface and view normal to the surface. Color measurements must also relate solely to color and not to such other material parameters as luster, texture, and shape.

FIG. 1. Spectral transmittance characteristics for various colors.



Tristimulus color specification

Color can be uniquely specified by three independent dimensions, x, y, and z. The dimensions' numerical values for a particular color are obtained by integrating the weighted contributions of all wavelengths in the absorption spectrum, and expressing each of them as a proportion of the sum of three integrals. The weighting occurs in two steps: the spectrum intensity at each wavelength is weighted according to the intensity of Illuminant C at that wavelength; then each wavelength is further weighted in proportion to each of three tristimulus spectrum specifications standardized by the CIE*. For convenience these specifications are referred to as the red, green, and blue specifications and the results of the integrations are the red, green, and blue tristimulus values.

The tristimulus values can be measured directly with a tristimulus colorimeter by viewing colored materials in Illuminant C. The light reflected from the sample is observed photoelectrically through three filters, *R* (red), G (green), and *B* (blue), whose transmission values at each wavelength are proportional to the appropriate weighting functions. Further filtering is provided in inverse proportion to the sensitivity-vs.-wavelength function of the phototube detector, so that the detector has effectively equal sensitivity at all wavelengths. The resulting photoelectric signals are proportional to the colored material's tristimulus values, X, Y, and Z.

The tristimulus specifications of the spectrum are chosen so that Y represents the luminous apparent reflectance of the color analogous to the gray scale of black and white photography; X is a rough measure of the intensity of red light in the color; and Z is roughly proportional to blue intensity.

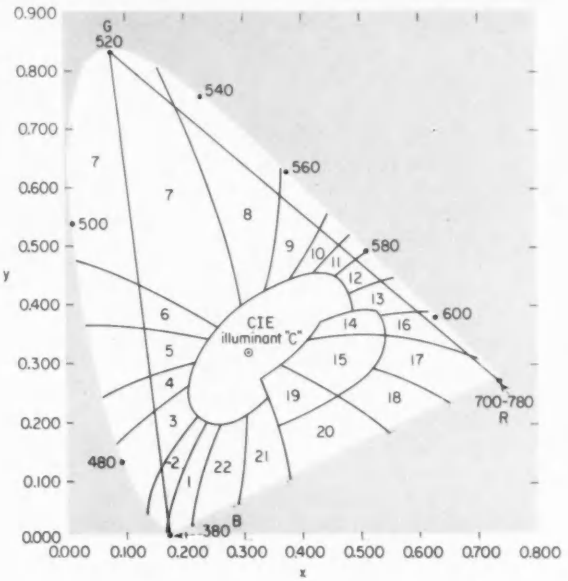
One customary way to specify colors is in terms of reflectance Y and coordinates x and y, where:

$$x = \frac{X}{X+Y+Z} \text{ and } y = \frac{Y}{X+Y+Z}$$

A chromaticity plot, Figure 2, aids in visualizing the relation of one color to another. The coordinates x and y are plotted in the plane of the page, and Y is marked near each point or on a separate scale.

Chromaticity coordinates derived from tristimulus values fail, however, to represent colors in a way that correlates readily with visual judgment. Color differences of equal size would appear as different-sized ellipses, depending on their location on the chromaticity diagram. One reason for this nonuniformity is that the human eye perceives colors not on a linear scale like photoelectric detectors, but on a more-or-less exponential scale.

* Commission Internationale de L'Eclairage (International Commission on Illumination).



1. Bluish purple
2. Purplish blue
3. Blue
4. Greenish blue
5. Blue-green
6. Bluish green
7. Green
8. Yellowish green
9. Yellow-green
10. Greenish yellow
11. Yellow
12. Yellowish orange
13. Orange
14. Orange-pink
15. Pink
16. Reddish orange
17. Red
18. Purplish red
19. Purplish pink
20. Red-purple
21. Reddish purple
22. Purple

FIG. 2. CIE chromaticity diagram shows the location of standard colors.

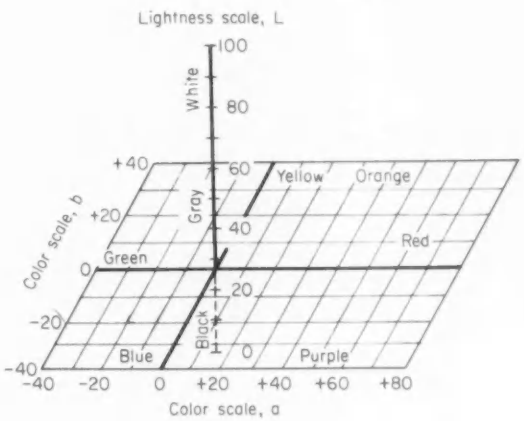


FIG. 3. Isometric projection of a uniform color space. In routine work the a and b dimensions are plotted rectangularly and the third dimension is shown alongside on a vertical scale.

Uniform color scales rectify the chromaticity diagram derived from tristimulus values and provide a three-dimensional system that correlates well with visual perception. Figure 3 shows a UCS diagram in which coordinate a is a measure of redness-greenness, coordinate b of yellowness-blueness, and coordinate L of blackness-grayness-whiteness.

The following are the preferred equations for rectifying the shape of the chromaticity diagram using colorimeter red, green, and blue readings.

$$L = 24.14\, G^{1/3} - 15.36$$

when:

$R > G$: $a = 125\,(R^{1/3} - G^{1/3})$; a is positive (redder)
$R < G$: $a = 105\,(R^{1/3} - G^{1/3})$; a is negative (greener)
$G > B$: $b = 30.5\,(G^{1/3} - B^{1/3})$; b is positive (yellower)
$G < B$: $b = 53.6\,(G^{1/3} - B^{1/3})$; b is negative (bluer)

where $R = 1.02\,X$; $G = Y$; and $B = 0.847Z$

At the a=0 and b=0 point on the UCS diagram the color is neutral white, gray, or black, depending on the value of L. The weak (pastel) colors plot near this point and the strong (vivid or bright) colors plot further away. On uniform color scales one unit of color difference always has the same size regardless of its location and direction.

Three-dimension colorimetry

When a material is being investigated initially by colorimetric techniques it is best to use three-dimensional analysis. A full understanding of the results may often lead to short-cut one- and two-dimensional methods, but many color-controlled materials nevertheless require the measurement of all three dimensions to match a standard material's color.

Color tolerances plot on the CIE chromaticity diagram as ellipsoids of various shapes and sizes, depending on their location in the color space represented by the three dimensions. Color control can be based, therefore, on the distance from the standard to the sample relative to the distance from the standard to the tolerance ellipsoid. This procedure is widely used although it requires many chromaticity charts containing appropriate ellipses.

Color coordinates on uniform color scales give closer correlation to visual estimates and make it easier to handle color data and specify color tolerances. Color tolerances in UCS diagrams plot as a sphere of radius E, since all color dimensions have the same scales. The standard color point, the center of the sphere, is represented by the mutually perpendicular coordinates a, b, and L. A simple slide rule has been developed by du Pont for calculating, on the basis of the Pythagorean theorem, the total color difference from the differences in each of the three coordinates. Total color difference E serves as a practical method of stating product color tolerances between a sample and the standard it must match.

Two-dimension colorimetry

A widely used two-dimension color measurement is that for determining the degree of yellowness in products that are intended to be more or less white. Excessive yellowness in such materials as white pigments and paint, natural and synthetic fibers, DDT, sugar, and aspirin reduces the value of the product.

A complete and accurate measurement suitable for relatively small color differences, which does not inter-

pret grayness as yellowness and which correlates with visual judgments, is obtained from two of the three readings of a tristimulus colorimeter:

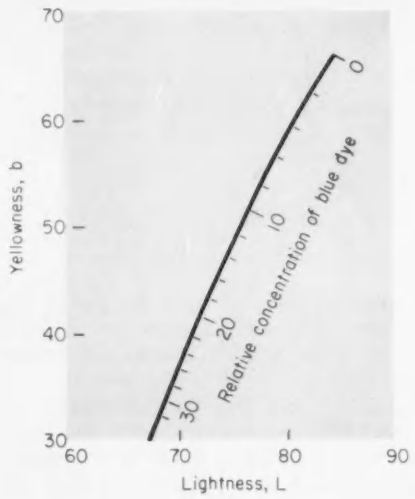
$$yellowness = (G - B)/G$$

Taking the ratio divorces the yellowness attribute from the lightness attribute.

More accurate scales sometimes are required for grading large differences in yellowness. Experiments based on the visual judgments of experienced color matchers shows that the *b*-dimension of the UCS scales correlates directly with yellowness.

Figure 4 shows a two-dimensional application of colorimetry, where the curve determines the concentration of a colorant (dye) in a substrate (paper). This figure shows how paper color varies with the amount of blue dye relative to yellow dye. As the blue concentration decreases (the yellow correspondingly increasing) the paper becomes lighter, as shown by the *L*-dimension, and yellower, as shown by the *b*-dimension. The *a*-dimension, redness or greenness, is not needed because it varies little in this application. The correct amount of dyes to make any color along the calibration can be predicted and used in preparing a smoothed series of color samples.

FIG. 4. Formulation corrections are made quickly and accurately, using the color-concentration relationship for dyed paper.



One-dimension colorimetry

Product analysis based on photoelectric measurement of absorption in monochromatic or near-monochromatic light is a branch of colorimetry often used in plant processes. This technique, described in the article on photometric ultraviolet stream analyzers[1], now will be considered in relation to materials that absorb visible light. Briefly, the absorption at a single wavelength is measured and correlated with the concentration or strength of the material to be determined. The same instruments, techniques, and precautions are required as for ultraviolet measurements. Photoelectric colorimeters have been adapted for visible-light detections in such applications as:

- dye color in gasoline
- strength of dye solutions
- discolorations in clear solutions
- off-color of powders and granular materials
- color of sheet materials
- turbidity of water and solvents
- concentration or strength of slurries, paints, smokes, or other particle suspensions
- gas analysis of chlorine, bromine, iodine, and nitrogen dioxide

The above analyses all refer to the determination of colored component strength in a visibly transparent medium.

A one-dimensional rough approximation to yellowness can be obtained by measuring a reflection or transmission factor to blue light since a yellow material is low in blue-light intensity. One way measures the blue-light absorption at 436 millimicrons or a nearby wavelength. Another way uses the reading through the *B* filter of a tristimulus colorimeter. Some misinterpretation may arise, however, by confusing grayness for yellowness.

Sampling

Thoughtfulness in developing sampling techniques pays off handsomely for colorimetry. For accurate control the sample must be representative of the material whose color is to be controlled.

Color measurements of such solids as paper and textiles require a smooth, flat, wrinkle-free surface. The sample area should be large enough so that the mottle of nonuniform samples and the variability in the number and depth of minor interstices in granular materials do not influence the measurement. The human eye averages minor irregularities in colored surfaces and avoids color discontinuities, but photoelectric instruments read what they see. Samples, therefore, should be clean.

Reproducible smooth-surface samples, such as ceramic tiles, plastics, and paint, are easily measured by colorimeters, but fibrous samples often are not. The latter can lead to nonreproducible readings because the spacing between fibers may vary and the fibers themselves may vary in twist, uniformity, etc. Several methods of preparing fibers for color measurement have been employed with a fair degree of success: the sample may be felted into pads, into compact wads, or woven into fabrics. The arrangement and size of the voids between fibers can never be perfectly duplicated from sample to sample, however, and voids act to make the sample appear darker. The measurement of yellowness, $(G-B)/G$ or UCS *b*, is not greatly affected by variable voids and therefore wads can be used to check the whiteness quality of undyed cotton and synthetic fibers. The measured color in random-fibered pads and wads is

weaker because of highlights than the true colors that would be seen in oriented fibers. The highlights come mostly from the surface of the fibers; hence they have the same white color as the light source.

Fiber yarns should be wound level on flat cards, Figure 5, for highest reproducibility of color measurement. The cards must be oriented properly to obtain minimum reflectance readings and thus avoid the highlight, white-light reflection. The measurement of textile fabrics during continuous processing is subject to errors owing to variable orientation and to differences in tension and wrinkles, so that measurements with such samples are not as accurate as those obtained with level-wound fiber cards.

The preferred method for measuring the color of wet materials such as paint and pigment slurries, is to spread the sample on a thin glass plate, Figure 5. The reflection color is then measured through the plate after the colorimeter itself has been standardized through the glass. The same technique is used for colored mortar, powders, and granular materials.

Continuous sampling often poses more problems than sampling for laboratory analysis Such opaque materials as wet pigment slurries or dry granular materials and powders can be reflectance-measured through a sight glass in a pipe line or vessel wall. Densely pigmented materials sometimes can be effectively color-analyzed by transmission measurements through a continuously flowing sample.

The measured value of the reflection color of a running web of paper, plastic coating, or a similar product is usually critical with respect to the distance between the sample and the instrument. Closely spaced rolls in the web-handling machinery in most applications assure reproducible distance and web flatness. Multicolor or mottled running webs for which average-color control is desired should be observed with a light beam several inches to a foot in diameter.

Color-measuring instruments

The human eye is a very discriminating detector of small color differences. Although an observer can name a color only to rough approximation, he can see the difference between two similar colors with high precision. Colorimeter measurements of reflection or transmission factors frequently have to be made to within 0.1 percent to achieve precision equal to the human eye. The precision required in colorimeters, therefore, is usually better than that required by other analyzers.

The basic instrument of color measurement is the spectrophotometer, a laboratory instrument not adaptable for routine operation in the environment of most manufacturing plants, but extensively used in control laboratories. Instruments of this type suitable for color control include those made by General Electric, Beckman, and Applied Physics Corp.

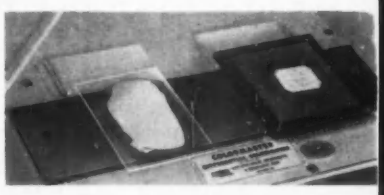
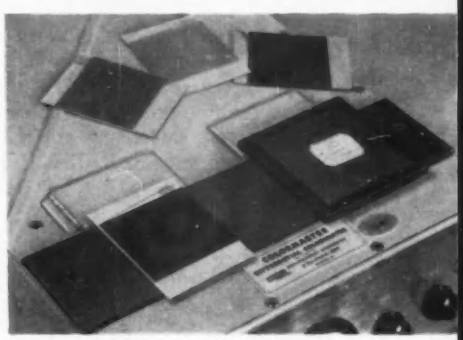


FIG. 5. The Colormaster tristimulus differential colorimeter produces readings on a counter. A mask permits a range change of ten to one. Also shown are level-wound card samples, below, and a pigment sample, right, ready for measurement on the colorimeter.



The GE spectrophotometer[2] was designed specifically for color measurement problems. Its spectral distribution curve may be used directly for color control, or, for color control applications, may be integrated to provide tristimulus color values. These, in turn, may be mathematically or mechanically manipulated to provide CIE or UCS color coordinates. Under optimum conditions and with careful operation, this instrument is sufficiently accurate for the majority of color control problems. However, it provides more than the essential minimum information and its operation is time-consuming. It is ideal for research, but not for process control.

The Beckman and Applied Physics (Cary) instruments were designed for laboratory measurements of spectral transmittance at ultraviolet to near-infrared wavelengths, but with accessories for reflectance measurements they also can be used for reflection colorimetry at visible wavelengths. These two instruments differ from each other and from the GE instrument in illuminating and viewing conditions. They are best suited for strength or concentration measurements by color analysis at a single wavelength and for color matching where a sample must match the standard at all wavelengths.

Abridged spectrophotometry is the name sometimes applied to color measurement with colorim-

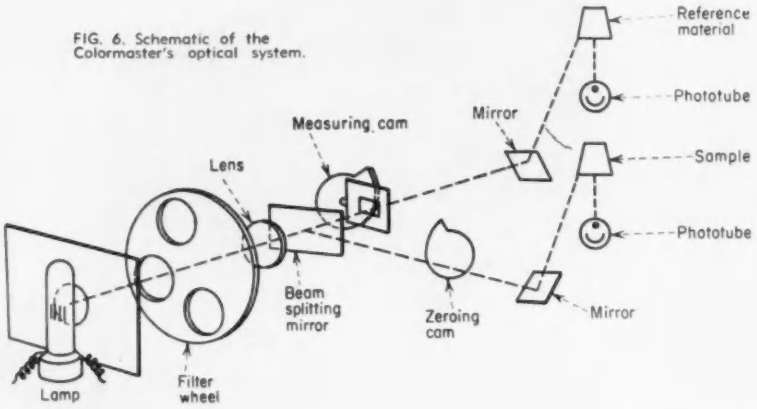


FIG. 6. Schematic of the Colormaster's optical system.

eters employing narrow-band filters. The abridgement comes about because a practical instrument provides only a few wavelengths. The band of wavelengths passed by the filters is broader than the nearly-monochromatic light in spectrophotometers. The abridged instrument usually is used for making strength determination or concentration analyses, rather than color measurements in the literal sense. Most filter colorimeters are not sufficiently precise for uses where color itself is the variable to be controlled, and only a few of them are adapted for reflecting materials.

The Beckman flow colorimeter, the MEECO photoelectric analyzer, and the Hallikainen flow colorimeters are among the commercially available instruments suitable for in-process applications. These have been used for monitoring city water supplies, determining discoloration of nominally clear solvents, determining concentration of greenish chlorine gas or reddish nitrogen dioxide, etc.

Tristimulus colorimeters, widely used in industrial laboratories, employ tristimulus filters and measure CIE tristimulus values. Makes differ widely in the way they measure, in the way they display data, and in their illuminating and viewing conditions. The significant advantages of each are:

▶ The Gardner Color and Color Difference Meter (Henry A. Gardner Laboratory) contains a built-in computer whose output is in the coordinates of a UCS system roughly approximating Figure 3.

▶ The Color-Eye (developed by Pittsburgh Plate Glass Co. and manufactured by Instrument Development Laboratories) reads directly in terms of the ratio of tristimulus value, sample to standard, and operates fast with minimum sample handling.

▶ The Colormaster differential colorimeter, Figures 5 and 6 (developed by du Pont and manufactured for commercial sale by the Manufacturers Engineering & Equipment Corp.), can be used for tristimulus and monochromatic measurements. These measurements are made by comparing a sample with a perfect reflecting white. In practice, the perfect white is replaced by a secondary standard white (or other color) of ceramic or polished opaque glass whose reflectance values are independently known. The colorimeter is zeroed, or standardized, to read the correct values on the standard. The standard then is replaced by the samples whose color values for each of the three colorimeter filters are read in sequence from a counter dial shown in Figure 5, after the instrument meter has been nulled to zero.

The measurements are made by comparing the light reflected by the sample with the intensity in a reference beam that passes through the same colorimeter filter, Figure 6. The reference beam is attenuated until it exactly equals the intensity from the sample.

A series-aiding phototube ratio-bridge circuit provides utmost sensitivity and stability. Circuit response, as seen in the magnitude of the unbalance indicated by the null meter, is proportional exclusively to the ratio of intensities in the two light beams. Thus the sensitivity, or minimum detectable reflectance difference, is a constant and very small percentage of the reflectance value of the sample, even for dark samples with low intensity.

The instrument controls are designed for easy manual operation. The zero control sets the light level used for the measurements so that the response of the two phototubes, as indicated by the null meter, is nearly equal for each of the filters. Three fine controls, blue, red, and green, at the upper right refine the balance setting at standard values by adjusting a portion of the resistance arms of the phototube bridge circuit. The selector switch for these fine zero controls also moves the corresponding tristimulus filter into the light beam. The null meter ordinarily operates at low sensitivity to keep its pointer on scale. As the balance is refined, the operator depresses the sensitivity button to achieve bridge balance with meter range at a higher sensitivity of 50-0-50 mv.

It is desirable to periodically check the performance of tristimulus colorimeters to maintain their high sensitivity and stability. Such checking includes setting the zero and the sensitivity, and cleaning at six-month intervals to remove dust and obscuring films from optical components.

Examples of abbreviated color-measuring systems in process control are the one- and two-dimensional systems for grading and automatically sorting tomatoes and oranges, for grading nominally white plastic chips and automatically segregating off-color ones, and for continuously controlling the blending of pigment slurries to the proper strength.

1. *PHOTOMETRIC STREAM ANALYZERS—VERSATILE INSTRUMENTS FOR MEASURING COMPOSITION*, Leo G. Glasser, "Control Engineering", October 1957, pp. 87-95.

2. *COLOR BASICS FOR THE CONTROL ENGINEER*, O. H. Olson, "Control Engineering", October and November 1955.

Positioning Systems - II

JOHN D. COONEY and BYRON K. LEDGERWOOD, Control Engineering

This is the second part of Control Engineering's staff-researched report on 31 domestic and foreign numerically-controlled point-to-point positioning systems. The material on the first 12 systems covered in the January issue is followed here by comprehensive descriptions of ten more controls. The third and last article in this series will appear next month.

CHECKLIST OF SYSTEM CHARACTERISTICS – II

MANUFACTURER	COST	EQUIPMENT FURNISHED	ACCURACY	AVERAGE POSITIONING TIME OR SPEED BETWEEN POINTS	STORAGE MEDIA	STORAGE CODE	TYPE OF MEASURING SYSTEM
FUJI TSUSHINKI MANUFACTURING CO. No. 1015 Kamikodanaka Kawasaki, Japan *no.* **13**	$4,100	Complete two-axis system plus turret selection equipment developed specifically for Wiedemann RA-41 P punch press	± 0.07 mm (about ± 0.0028 in.)	3 meters per min (118 in. per min)	6-channel Japanese teletype tape, 22 mm wide, cellulose acetate	Modified binary-coded decimal	Perforated aluminum disc-phototransistor pulse generator (incremental)
WANG LABORATORIES, INC. 37 Hurley Street Cambridge 41, Mass. *no.* **14**	Not costed	Varies with application	±0.0005 in.	Function of servos selected	8-channel, 1-in. punched tape	Binary-coded decimal	Special coded-disc converter (absolute)
THE GOVERNMENT MECHANICAL LABORATORY 132 Sumiyoshi-cho Suginami-ku Tokyo, Japan *no.* **15**	Not costed	Complete two-axis control	± 0.002 mm (about ± 0.00008 in.)	2 meters per min (about 78.7 in. per min)	6-channel Japanese teletype tape, 22 mm wide, cellulose acetate	Modified binary-coded decimal	Fine and coarse optical measuring systems (incremental)
TOPP INDUSTRIES, INC. 5221 West 102 Street Los Angeles 45, Calif. *no.* **16**	$15,000	Two-axis table and control console	± 0.001 in.	50 in. per min (rapid traverse)	Magnetic tape, ½-in. wide, 7-channel	Incremental pulse trains	Counter consisting of stepping motor and differental transformer (incremental)
MICRO-POSITIONER DIV. TOPP INDUSTRIES, INC. 5221 West 102 Street Los Angeles 45, Calif. *no.* **17**	$9,600	Complete two-axis table and control console	± 0.001 in.	90 in. per min (rapid traverse)	¾-in. steel tape	Mechanical indentations	Precision switches sense location of indentations (absolute)
ADVANCE INDUSTRIES, INC. 640 Memorial Drive Cambridge 39, Mass. *no.* **18**	$25,000 to $30,000	Complete machine tool including positioning table, drill head, tape reader, control unit	±0.001 in.	150 in. per min (rapid traverse)	4-in., 32-channel punched tape	Binary-coded decimal	Four synchos geared to leadscrew (absolute)
ELECTRONIC CONTROL SYSTEMS, INC. 2136 Westwood Blvd. Los Angeles 25, Calif. *no.* **19**	$20,000 $2,000	Two-axis table and control console Desk-type calculator tape preparation unit	± 0.0002 in.	100 in. per min (rapid traverse); 2 sec	8-channel ⅞-in. wide paper or plastic tape	Binary-coded decimal	Combination of coded disc and resolver (absolute)
FERRANTI, LTD. Ferry Road Edinburgh 5, G.B. *no.* **20**	$3,000 per axis (plus cost of tape reader and drive servos)	Complete control equipment including measuring transducer	± 0.0001 in.	2 sec	Standard 5-channel teleprinter tape	Binary-coded decimal	Optically read diffraction gratings (incremental)
BARNES ENGINEERING CO. 30 Commerce Road Stamford, Conn. *no.* **21**	$3,000 per axis	Complete control (accessories additional)	± .0005 over 18 in. of travel	50 in./min	Special 4⅝-in.; 32-channel Mylar tape	Conventional binary	Binary – coded disc on printed board (absolute)
LABORATORY FOR ELECTRONICS, INC. 75 Pitts Street Boston, Mass. *no.* **22**	Not costed	Two-axis positioning table, automatic drill head, tape perforator and reader	± 1/128 in.	1 sec	8-channel, ⅞-in. wide paper or plastic tape	Conventional binary	Gray – coded disc operated from precision rack (absolute)

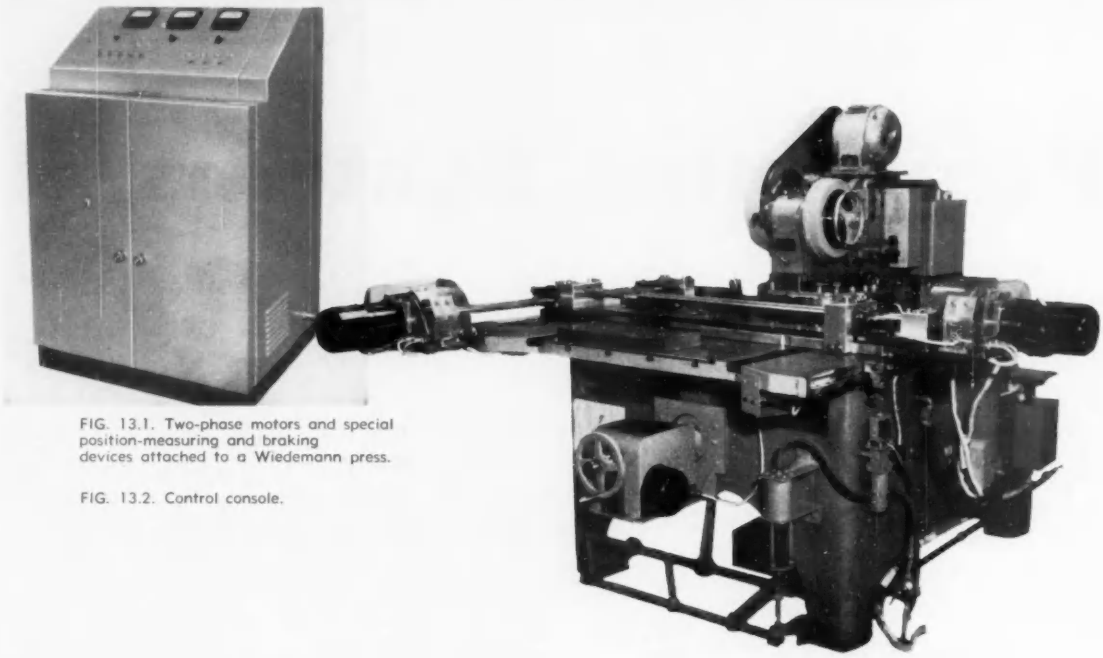


FIG. 13.1. Two-phase motors and special position-measuring and braking devices attached to a Wiedemann press.

FIG. 13.2. Control console.

System

13

FUJI TSUSHINKI MFG. CO.

This unique low-cost Japanese system was developed specifically for punch selection and two-axis positioning on new and used Wiedemann turret punch presses, Figure 13.1; it can be adapted to other types of machines without major modifications. The system consists of a keyboard-type tape punch, control console (Figure 13.2) power servos, and position transducers. The punched-tape recorded information medium uses a special code, but the input to the tape punch does not; its decimal-metric form allows drawing-dimension information to be used directly. The system is quite new and development has only recently been completed, so that although the company has ten bids out, none has been delivered or sold.

The system is completely digital, and table position is measured by incrementally determining leadscrew angular position. The basic increment of table motion (resolution) is 0.1 mm (about 0.0039 in.) and the system is accurate to within 0.07 mm (about 0.0028 in.). Table travel is 600 by 600 mm (about 23.6 by 23.6 in.) and maximum traverse speed is 3,000 mm per min (about 118 in. per min). Speed is limited by the servomotors. The principal data-handling system components are 80 relays, 300 parametrons, six thyratrons, 15 tubes, two phototransistors, and 30 germanium diodes. Backlash is prevented by a special loaded leadscrew nut.

Several safety and checking features are included. Panel-mounted meters indicate the voltage and current in the main circuits, and alarm lamps light under the following conditions: interruption of operation, overrun of the specified position, failure of relay contacts, and failure of fuses. In addition, self-checking features of the special 2-out-of-5 and 2-out-of-6 codes used to record information on the tape permit no more and no less than two holes in each row.

The two most interesting portions of the system are the parametron counter and logic circuits, and the specially designed combination angular-position-measuring, damping, and braking device attached to the machine leadscrew.

Input coding and data handling

Figure 13.3 shows a typical series of tape fields and the decoding table. Note from the table that the digits 0 through 9 are represented by a 2-out-of-5 code, while the signs and sequencing instructions are represented by a 2-out-of-6 code. A block of information on the tape contains the punch designation and positioning information for a sequence of holes to be punched by the same punch. When the code digit *A* is used, it indicates that a block of information is complete and a new punch must be designated for the next hole. The code digit *C* is for repeat operations, when the *X* or *Y* coordinate for the new hole is the same as it was for the last one. Code digit *B* indicates cycle completion. The punch and table are restored to the original position. Code digit *D* is used to simplify starting the tape on the reader.

In the typical fields shown here, punch 3 (Z_1) is used to punch holes 1 and 2. The *C* digit codes indicate that the coordinate X_1 is the same as the previous *X* coordinate, and that the Y_2 coordinate is the same as

Y_1. The first A digit code tells the system that the next code (10) represents the new punch number. The coordinate designations represent the positive or negative distance between the new point and the last point in tenths of millimeters. The data-handling logic circuitry is designed to properly identify the various types of coded information if the permissible sequence of coding is followed.

The tape is standard six-channel Japanese Teletype tape of cellulose acetate. It is 22 mm wide. Continuous tape loops can be used for repetitive identical workpieces.

In reading the tape, the first coded number selects the proper punch. When this operation is completed, the X coordinate is read into relay storage and then preset into the parametron counter. The sign accompanying the coordinate information determines the direction of motor and leadscrew rotation, while the number stored in the counter represents the total number of increments that must be traversed to reach the new position. The incremental position indicating device (described in the next section) then feeds back pulses representing incremental movement until coincidence is reached and the table braked. While the X-axis positioning is in process, the relay register is cleared and the Y-axis coordinate is stored in the register. This reduces data handling time, since as soon as the X-axis is positioned, the Y-axis coordinate is read into the counter. When the correct punch has been selected and the two axes positioned, the punching operation can be initiated. After a switch closure indicates that the punching operation has been completed, the next cycle starts automatically. Figure 13.4 shows a simple schematic of the system.

Actuation and position measurement

Probably the most unique device in the system is the one that performs the functions of incremental-angular-position measuring, damping, and braking, Figure 13.5. This device consists of an aluminum disc with 12 small holes on an inner radius for pulse generation, and 12 armatures on an outer radius for braking. This disc and the drive motor are attached directly to the leadscrew of the machine table. The motor is of the two-phase induction type, operated full-on or full-off without a tube amplifier. When a new position has been preset into the parametron counter, the motor runs full speed in one direction or the other, depending on sign. Pulses are generated each time one of the pulse-

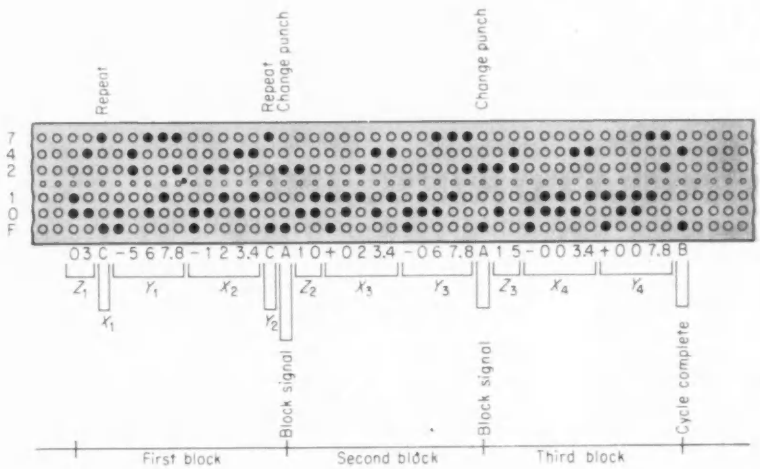


FIG. 13.3. Typical tape and decoding table.

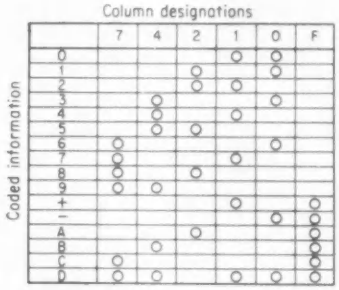
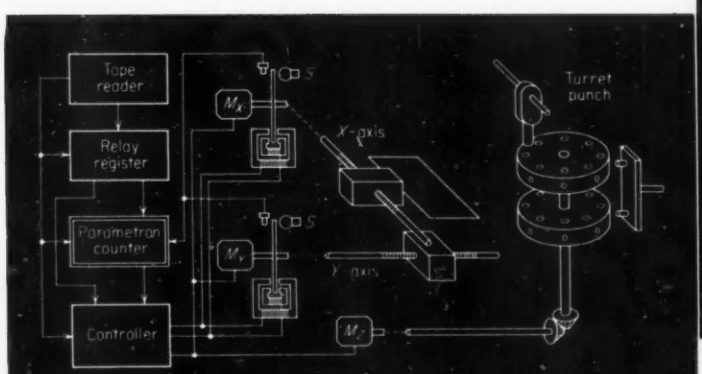
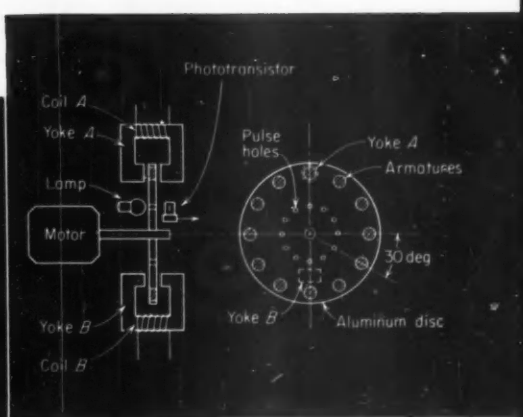


FIG. 13.4 (below). Simplified schematic of Fuji Tsushinki system.

FIG. 13.5. Details of position-measuring, damping, and braking device.





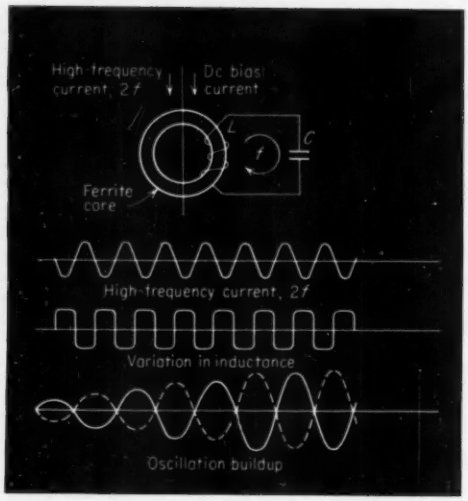


FIG. 13.6. The basic parametron and its wave shapes.

generating holes in the aluminum disc permits light from the lamp to reach the phototransistor. These pulses reduce the contents of the counter. When a number of pulses 39 less than the preset value has been counted, coil *B* on yoke *B* is energized and leadscrew rotation is damped by the eddy currents generated in the aluminum disc. When the preset value is reached, coil A of yoke A is energized and the leadscrew is stopped and held at the correct increment. The pitch of the leadscrew is such that 1/12 of a revolution is equivalent to 0.1-mm table motion.

The parametron

The parametron was originated by a research group at Tokyo University in 1954. As the name implies, it operates on the principle of so-called parametric oscillation, Figure 13.6. That is, when a high-frequency current of $2f$ (about 2 megacycles) is coupled to an *LC* circuit tuned to f, the inductance of the coil varies with the $2f$ exciting current, and an oscillation of frequency f is started in the tuned circuit, which reaches a constant amplitude within several cycles. The tuned circuit consists of a coil wound on a nonlinear ferrite core and a capacitor. The important point is that the oscillation has two discrete phase relationships referred to the exciting current, 180 deg out of phase.

These two states are called 0 and π, and correspond to the two states in flip-flops and other bistable devices. At the beginning of oscillation, a small signal of either the 0 or π sign is supplied to the parametron and amplified to a constant magnitude with corresponding sign, and holds this state until the exciting current is cut off. As a bistable device, a parametron can be used for logical operations and storage, and in shift registers and counters. Its main advantages are long life expectancy, low cost, and noncritical circuit design.

System

14 WANG LABORATORIES, INC.

Based on experience gained with the continuous-path equipment, Wang Labs is entering the point-to-point positioning field with a system known as Weditrol-Positioning. No standard model is available, and systems will be designed to fit specific applications. The basic system logic, however, is standard.

The input media is standard eight-channel 1-in. wide punched paper tape, coded in binary-coded decimal. The keyboard-input tape-preparation unit converts from decimal. The system uses a special decimal-coded absolute digital position transducer and comparator, somewhat similar to a standard three-stage coded-disc converter. With a 10-pitch leadscrew, the maximum axis travel is 99.999 in. and the resolution is 0.001 in. Overall accuracy depends on the specific application; however, the basic system is accurate to within 0.0005 in.

Figure 14.1 shows a simplified schematic. The tape is read a line at a time, and the positional instructions and auxiliary commands are stored in relay buffer storage. Selector switches can be used for manual input.

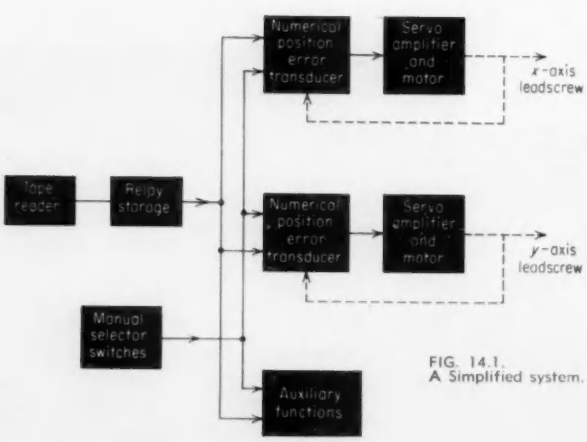


FIG. 14.1. A Simplified system.

Position transducer

The most interesting item in the system is the position-transducer/comparator shown in Figure 14.2. This unit consists of three commutator discs with their wipers geared together and coupled to the leadscrew. The first two stages essentially count leadscrew revolutions, while the third stage divides the last revolution into 100 parts to obtain the desired resolution of 0.001 in. Using bridge-balancing techniques, the first two stages provide only a directional error signal and the leadscrew runs at full speed in the direction to null the circuit. The third stage provides an error signal that is both direction- and magnitude-sensitive. This results in proportional action during the last-turn positioning operation.

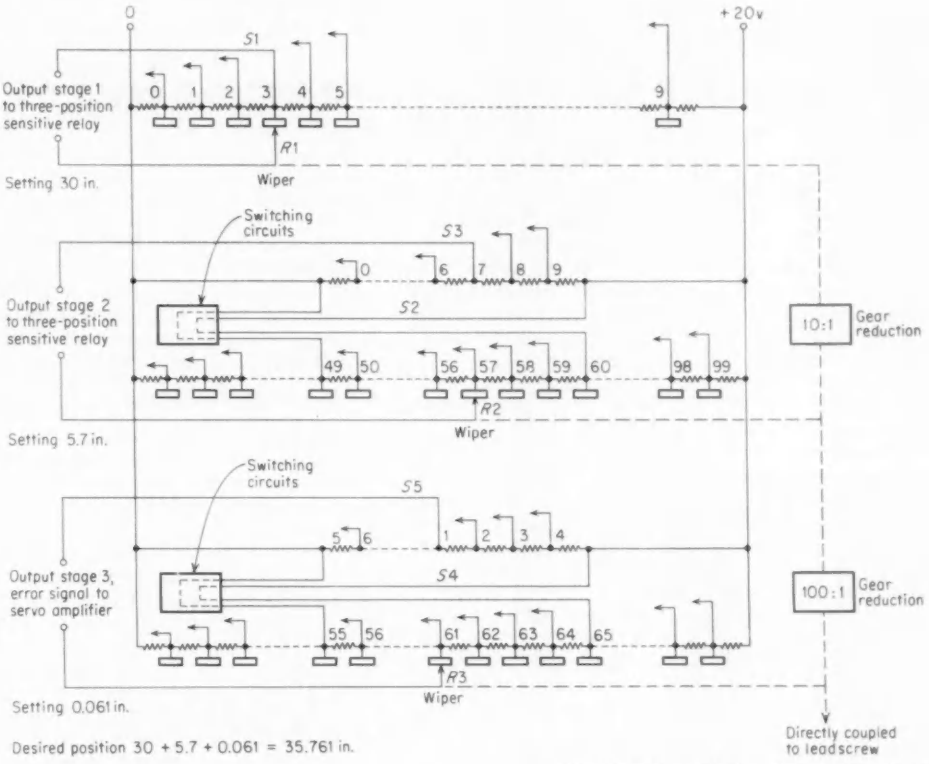


FIG. 14.2. Schematic of special error transducer.

Assume that the desired position is 35.761 in. The first-stage commutator disc has ten segments with precise resistors connecting succeeding segments. The wiper is geared 1,000:1 to the leadscrew, so that this stage positions to the nearest tens of inches. Through switch S1, the stationary number 3 segment (for 30 in.) is connected to one side of a polarized three-position sensitive relay. During the nulling period, the sensitive relay saturates the servo amplifier either positively or negatively (depending on error sign) and drives the table until the wiper nulls at number 3 segment under bridge action. The error logic circuit is designed so that the output of the first stage always overrules the outputs of the succeeding two stages.

When the first stage nulls, control is switched to the second stage, which has a 100-segment commutator. The wiper is geared 100:1 to the leadscrew so that this stage handles the units and tenths decades. The setting is 57 for the assumed desired position of 35.761 in. This stage also controls a polarized three-position sensitive relay and nulls in a manner similar to the first stage, except that a ten-resistor network is paralleled with the commutator circuit as shown in Figure 14.2. Switch S2 connects this network to the commutator segments in such a manner that the desired segment (57) is located near the middle of the ten-segment span. Then switch S3 connects shunting resistor 7 to the sensitive relay, and the table moves in the proper direction until wiper *R*2 nulls on segment 57. This technique of using the parallel network means that the bridge circuit need only differentiate between ten different positions, rather than the 100 positions it would have to identify if the second stage worked like the first. Again, the second-stage error always overrules the third-stage error.

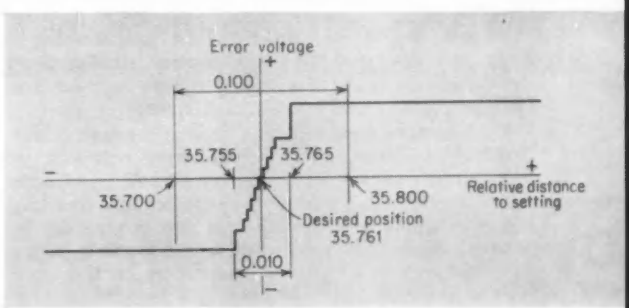


FIG. 14.3. Voltage/position-error characteristic.

The third stage is identical to the second except that it is directly connected to the leadscrew. Thus, the 100 segments represent the hundredths and thousandths decades, and the setting here is at segment number 61 for 0.061 in. Note that switch S4 again connects the shunting resistor network so that the desired segment is near the center of the bridge. In this case, bridge output is connected directly to the servo amplifier so that the system approaches the final position in a stepped proportional manner, Figure 14.3.

The voltage vs. position error characteristic is somewhat nonsymmetrical about the null point. Double wiper sets ambiguity and excessive nonsymmetrical characteristics of the error voltage.

System

15 JAPANESE GOVT. MECHANICAL LAB.

Although still in the development stages, this system for positioning a precision jig bore from punched tape shows signs of being one of the most interesting. Planned to mate with a specially designed machine that will be completed in April 1959, the system includes two-axis positioning of the jig bore carriage plus control of many auxiliary functions. Position measurement is incremental from a combination of linear optical scales. The six-channel tape code is modified binary-coded decimal, but since the electric tape punch automatically converts from decimal-metric, dimensional information can be entered directly.

The proposed table travel is 800 mm (about 31.5 in.) in X and 600 mm (about 23.6 in.) in Y, and the expected accuracy is extremely high. Programming resolution is to be 0.001 mm (about 0.000039 in.) and overall accuracy 0.002 mm (about 0.000079 in.). Maximum traverse speed is 2 m per min (about 78.74 in. per min) and final positioning creep speed is 1 mm per min (about 0.04 in. per min). It is estimated that the final system will contain about 3,300 parametrons, 100 relays, and 50 tubes.

An unusual system in almost every respect, its most interesting features are these:

► *Two-tape input.* The input information is recorded on two tapes. The first, coordinate tape, includes hole number and positioning information, while the second, sequence tape, includes hole sequence and machining information.

► *Conversion of coordinates.* Tape programming is from an origin and coordinate system established on the workpiece; the data-handling system automatically converts to the machine coordinate system.

► *Parametron circuitry.* The logic and counter data-handling circuitry consists of parametron networks.

► *Coarse and fine linear position transducers.* Coarse positioning is accomplished by incrementally counting the graduations on a main scale, fine positioning by counting Moire fringes generated by a diffraction-grating sub-scale system. Digital compensation of the main scale is also included.

► *Coarse and fine servo drives.* Coarse positioning is accomplished by a hydraulic servo in the X axis and by an induction motor drive in the Y axis. Dc shunt motors are used for fine positioning in both axes.

► *Checking and display.* The 3-out-of-6 modified binary-coded decimal code incorporates certain self-checking features. All machining and sequential information is displayed on visual indicators for operator observation. Critical functions are interlocked with alarm lights.

Optical linear position transducer

To achieve the high-precision position required by this system, coarse and fine linear optical transducers are used. Coarse positioning is accomplished by counting the 1-mm-spaced graduations on a main scale, and fine positioning by counting the 0.001-mm-spaced Moire interference fringes generated by a diffraction grating sub-scale. Figure 15.1 shows a simplified schematic of this transducing system. The main scale is attached to the servo-driven machine carriage, and the optical and photoelectric detection system for this scale is fastened to the machine bed. A pulse is generated each time the detector passes a graduation.

During coarse positioning, the sub-scale system, together with its optical and photoelectric portion, is disconnected from the carriage. When the last main-scale graduation prior to the destination is reached, control transfers to the sub-scale and Moire fringes are counted for final positioning. Immediately before transfer, the sub-carriage carrying the sub-scale is connected to the main carriage through the rod, so that it moves with the main carriage.

When the proper number of Moire fringes has been counted, the carriage stops and is locked. Then the final position is a specified number of millimeters (main scale) plus a specified number of micro-meters (sub-scale) from the machine bed reference point. This two-level positioning technique is necessary because precision diffraction gratings the length of the entire travel are not practical.

It is also possible, by using the scales in an inverse manner, to determine the distance from an arbitrary point on the table to the table origin. In this case,

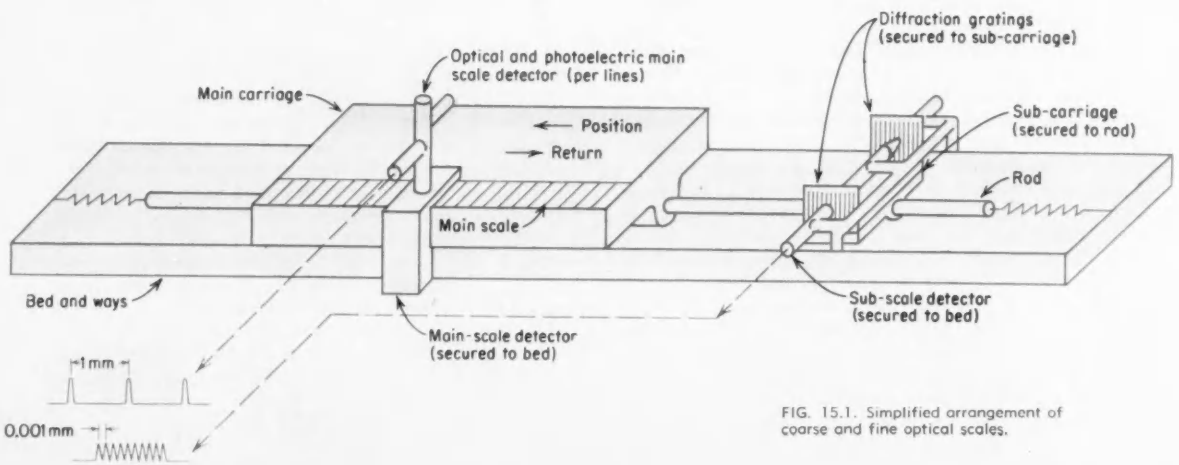


FIG. 15.1. Simplified arrangement of coarse and fine optical scales.

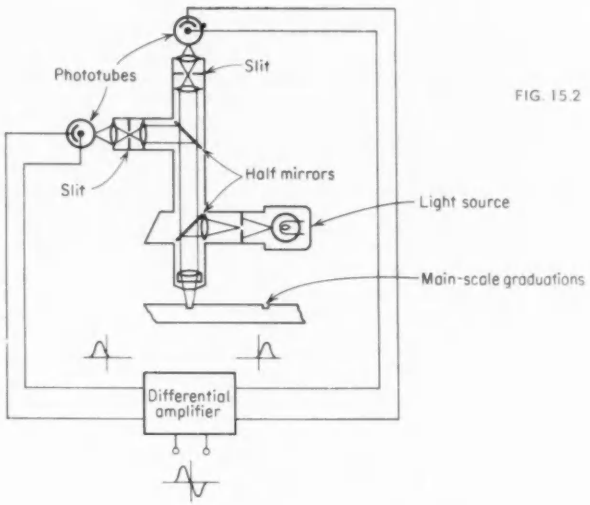


FIG. 15.2

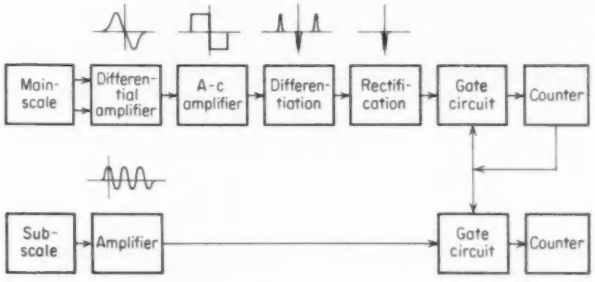


FIG. 15.3

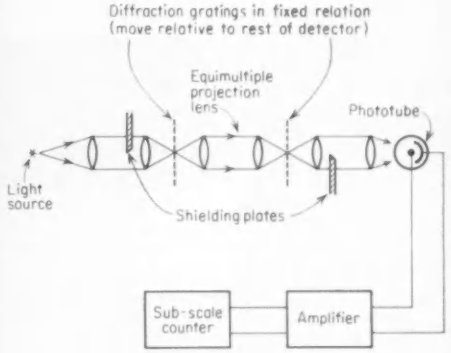


FIG. 15.4

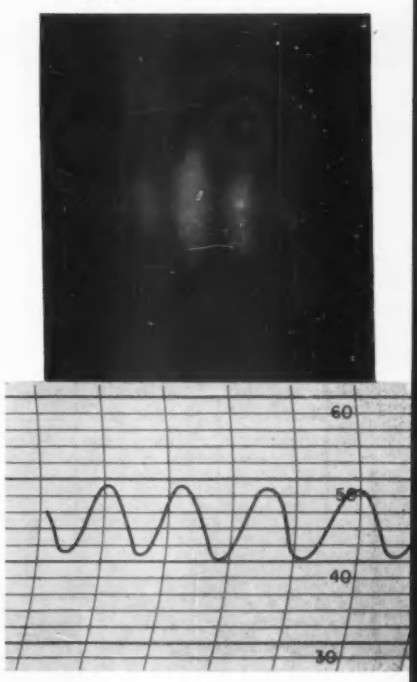


FIG. 15.5A

FIG. 15.5B

FIG. 15.2. Two-phototube system for reading main-scale graduations.

FIG. 15.3. Circuitry required to process pulse waveforms.

FIG. 15.4. Diffraction grating sub-scale system.

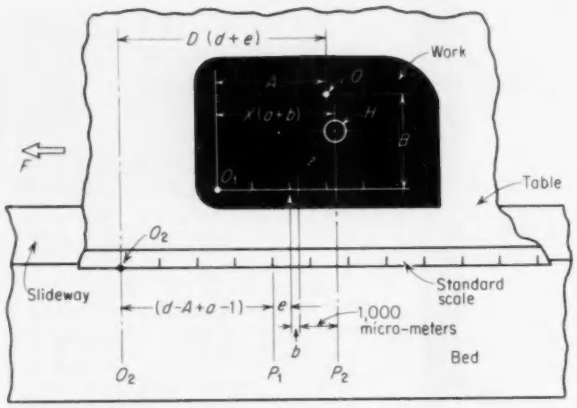
FIG. 15.5. Actual Moire fringes, A, and recording of phototube pulses generated by these fringes, B.

Moire fringes are counted until the first main-scale graduation is reached, then main-scale graduations are counted until the reference origin is encountered. This technique is used in coordinate conversion.

Figure 15.2 shows the optical detector for the main scale. As a main-scale graduation moves past the light source, the reflected light intensity varies sufficiently to generate a pulse from each of the two phototubes. A system with one phototube will produce a pulse, but the pulse shape is such that no precisely definable point (necessary for accurate counting and switching) is available. In the two-phototube system of Figure 15.2, the two slits are staggered relative to the light axis, so that, as the waveforms show, the output pulses are staggered a similar amount. These two pulses are then applied to the grids of a differential amplifier.

Figure 15.3 illustrates how the waveform from the differential amplifier is shaped to a square wave and amplfied in the ac amplifier, differentiated by an *RC* network to yield spike pulses at the leading and trailing edges of the square pulses, and then rectified to leave the single precise trigger pulse for gating and counting. Tests have shown that this pulse will repeat within 0.0008 mm (about 0.000032 in.). During positioning these pulses are counted until the total number coincides with the programmed millimeters. At this instant, the gate to the main-scale counter closes and the gate to the sub-scale counter opens. The time lag caused by this changeover is estimated to be 1 microsec.

Figure 15.4 shows the sub-scale system, with the optical sensing portion stationary during the sub-scale positioning portion of the cycle, and the diffraction gratings secured to and moving with the carriage. Moire fringes (light and dark areas) can be generated by tilting one



O – Datum point on work arbitrarily selected as a convenient precisely-locatable spot over which to center spindle after workpiece is secured to table.

O_1 – Origin of coordinate system on workpiece from which tape-recorded dimensions are taken. Selected to place all holes in first quadrant.

O_2 – Origin of basic table coordinate system from which positioning is done.

F – Direction of table movement during positioning.

X – Numerical value punched on tape; a in millimeters and b in micro-meters

A – Known distance from workpiece origin O_1 to point O over which spindle is initially centered. A must be an integral number of millimeters.

D – Numerical value between O and O_2; d in millimeters and e in micro-meters

$\overline{O_2 P_1}$ – Main-scale detecting zone.

$\overline{P_1 P_2}$ – Sub-scale detecting zone; $(e + b + 1{,}000)$ must be greater than or equal to 1,000 and less than 3,000.

H – Hole to be machined.

FIG. 15.6. Workpiece and table coordinate systems with nomenclature explanation.

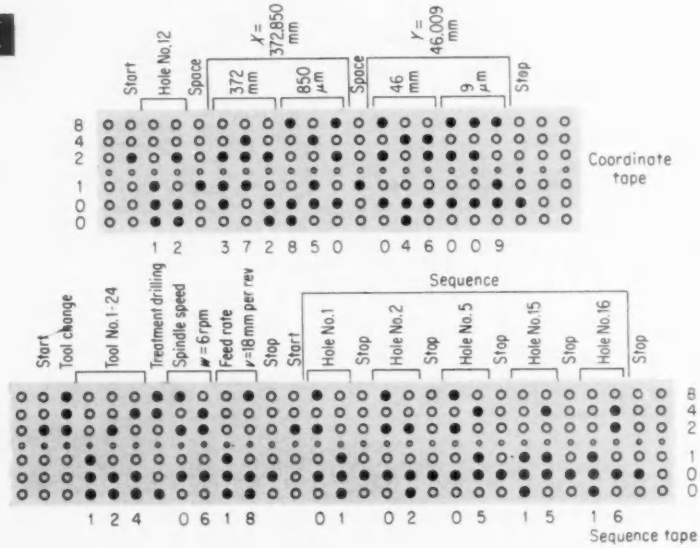


FIG.15.7. Typical coordinate and sequence tape fields and decoding table.

Column designations

Coded information	8	4	2	1	0	0
0	O		O		O	
1				O	O	O
2			O		O	O
3			O	O	O	
4		O			O	O
5		O		O	O	
6		O	O		O	
7		O	O	O		
8	O				O	O
9	O			O	O	
Start			O			
Space				O		
Stop					O	
Tool change	O	O	O			
Drilling	O	O				O

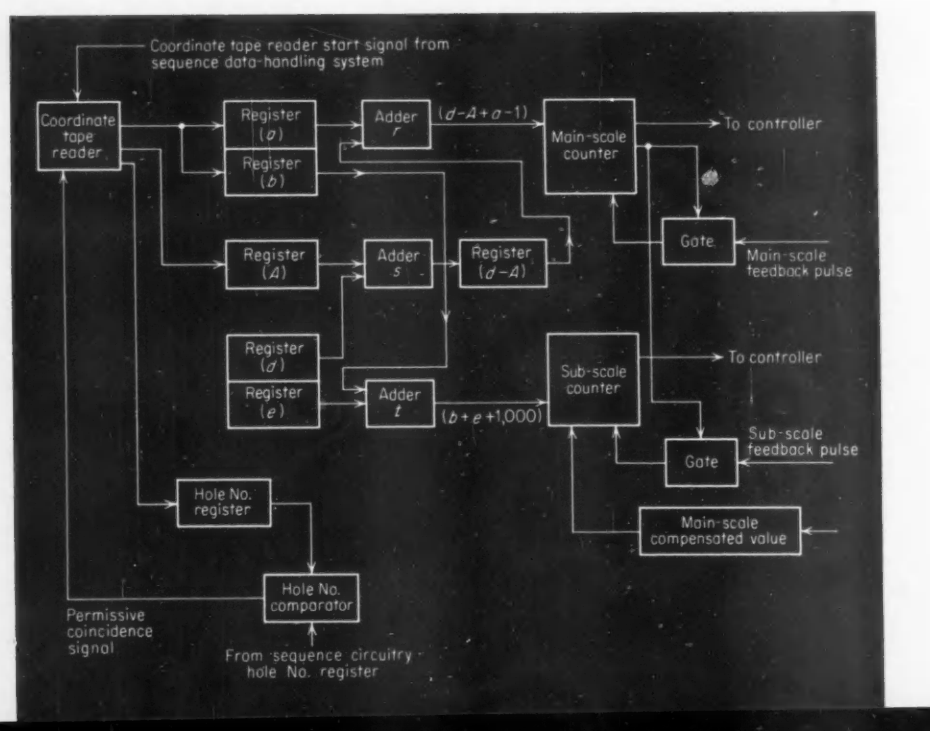


FIG. 15.8. Simplified version of coordinate data-handling circuitry.

precision diffraction grating with respect to another and moving them relative to each other past a light source. The spacing and brightness of the fringes depend primarily on the pitch of the gratings and the angle of tilt. Fringes can also be generated by the arrangement shown here, in which the tilted diffraction gratings are fixed relative to one another and then moved past the light source and detection system. This arrangement has certain advantages, since shifts in the location of the detection system relative to the gratings do not affect accuracy as much as changes in the relative positions of the two gratings. Figure 15.5A shows a typical Moire fringe obtained with this system, and Figure 15.5B shows recorded pulses from the phototube when the field of vision is constricted so that only one fringe is visible to the phototube at a time. The gratings used in this system have 600 lines per millimeter and yield one pulse per micro-meter. The system is said to be accurate and stable even under conditions of vibration.

Programming and tape preparation

The coordinate information punched in the tape is derived from a set of cartesian coordinates, with the origin placed so that all holes fall in the first quadrant. The actual positioning, however, is from the permanent-table cartesian coordinates. The conversion from one set of coordinates to the other is automatic, using the position transducer and the data-handling system.

As shown in Figure 15.6, an arbitrary workpiece origin O_1 is selected so that all holes to be machined fall in the first quadrant. The distances from this origin to the various holes (represented by X) are then recorded on the coordinate tape in terms of *a* millimeters and *b* micro-meters.

Next, another arbitrary point *O* is selected, an integral number of millimeters, *A* and *B*, from O_1 in the X and Y axes. This point should be one over which it is easy to precisely locate the spindle center line. Placing the spindle over this point and using the inverse measuring technique, the table is run back to the table origin O_2. As a result, the distance *D* from *O* to O_2 is recorded in the data system memory as *d* millimeters, and e micro-meters. The remaining calculations necessary to convert the workpiece coordinate system to the machine coordinate system are performed in the data-handling system. The main scale controls positioning from O_2 to P_1 and the sub-scale from P_1 to P_2.

As mentioned previously, two tapes are used to instruct this system: a coordinate tape and a sequence tape. Both tapes are standard six-channel Japanese Teletype tape, 22 mm wide and made of cellulose acetate. The coordinate tape, Figure 15.7, includes the number of each hole, the X distance from the hole to the workpiece origin in millimeters and micro-meters, and the Y distance. The sequence tape, in contrast, contains all of the information required to properly machine each hole and the sequence in which the holes are to be machined. As shown, coded information designating tool number, treatment (drilling, reaming, boring, etc.), spindle speed, and feed rate is followed by the coded numbers of the holes that are to be machined in this manner. This technique dictates that the coordinate tape reader be able to search for the code corresponding to the called-for hole number each time, either by running the tape in a continuous loop or by using a reader that can run in both directions.

Note that a 3-out-of-6 modified binary-coded decimal code is used for the digits 0 through 9, and for the tool change and treatment designations. This permits certain self-checks against coding errors. The remainder of the code designations use a 1-out-of-6 code. A variety of combinations is available for special instructions.

Data-handling circuitry

Because two tapes are used there are essentially two separate portions to the data-handling circuitry: the coordinate portion and the sequence portion. In both cases the tapes are read a line at a time, so that parametron buffer storage is required. To understand how the coordinate system works refer to Figures 15.6 and 15.8. With the spindle centered over point *O* and the workpiece secured to the table ready for machining, the table is backed up to the table origin O_2. This causes the position transducer to inversely measure distance *D*, of which the millimeter portion is stored in register (*d*) and the micro-meter portion in register (e). Then the coordinate tape reader starts on a signal from the sequence circuitry. First the value of A is read in (distance from point *O* to workpiece origin O_1) and stored in register (A). This need only be done once, at the start of a run, since A remains constant for the same workpiece. Then the X value, consisting of *a* in millimeters and *b* in micro-meters, is read in and stored in registers (a) and (*b*) respectively. All the necessary information is now available to the data system to properly position the table.

Note from Figure 15.6 that the main scale is in control over a distance $(d - A + a - 1)$. This number of millimeters is calculated by subtracting A from *d* in adder s and adding $(a - 1)$ to this sum in adder *r*. The result is stored in the main-scale counter and the table is driven until this number of pulses has been fed back. At coincidence the gate to the sub-scale counter is opened and control reverts to the sub-scale.

Again referring to Figure 15.6, the sub-scale is in control for a distance $(b + e + 1{,}000)$. This distance in micrometers is determined by adding *b* to $(e + 1{,}000)$ in adder *t*, the result being stored in the sub-scale counter. The table moves until the number of fed-back sub-scale pulses equals the number stored in the counter.

To prevent main-scale errors from affecting overall positioning accuracy, compensation is included. Essentially this is done by storing a calibration curve in a digital memory, Figure 15.8. A predetermined correction in micro-meters is stored for each main-scale graduation. When control is switched from the main scale to the sub-scale, the proper correction for the main-scale graduation at which switching occurred is withdrawn from the compensating memory and added to or subtracted from the contents of the sub-scale counter. This is the reason for having the sub-scale in control for the extra 1,000 micro-meters. Otherwise, it would be possible for $(b + e)$ to be less than a subtractive correction and the correction could not be made.

Before reading in the coordinate information as outlined above, it is first necessary to read in the hole number to make sure it is the correct hole as called for by the sequence tape. The contents of the hole-number register is compared with the contents of the sequence-circuitry hole number register, and if the two are the same a signal is sent to the coordinate tape reader, permitting the coordinate data to be read into the system.

FIG. 16.1. Two-axis table and control console.

FIG. 16.2. Control panel for original system.

System

16 TOPP INDUSTRIES, INC.

The original Topp unit, Figure 16.1, differs considerably from the other positioning systems. Magnetic tape is used as the recorded information medium, and the positional data is recorded by actually moving the table from point to point rather than in some type of tape-preparation unit. Thus the system includes only the two-axis positioning table and the control console. Since the table has an infinitely variable speed range along each axis, and since the two axes can be tied together electrically, the system can also be used for milling along either axis or at a 45-deg angle to the axes. In addition, continuous-path contour milling can be accomplished by properly synchronizing the motion of the two axes during recording, although a separate recording system is under development that will simplify this mode of operation. A separate tape-preparation unit for point-to-point positioning (consisting essentially of preset counters), also under development, will permit programming the magnetic tape without moving the table. Although the prototype model of this system has been operating on the factory floor for some time, no final system has been announced and improvements are continually being added.

This is an incremental digital system, in which a special electromechanical counter geared to the leadscrew essentially counts pulses read from magnetic tape. Each pulse corresponds to 1/1,000 of a leadscrew revolution, or 0.0002 in. of table travel. Accuracy is conservatively said to be plus or minus 0.0001 in., including all leadscrew and gearing errors. Traverse speed can be varied from zero to a maximum of 50 in. per min. The 14-in. magnetic tape reels will hold enough tape for 40 min of operation, not counting machining time when the tape is stopped. The table has a 10 x 20 in. travel and is driven by two 200-watt, 60-cycle servomotors geared to preloaded ball-bearing leadscrews. The control console, Figure 16.2, has all of the controls on top and the magnetic tape mechanisms in the rear. It is 22 x 22 x 48 in. high.

The present system has one auxiliary relay for controlling the machine quill; however, by proper sequencing with an internal tape-stop function, a second external function such as control of a drill turret can also be obtained. And an auxiliary system has been developed that will handle an unlimited number of on-off functions.

It is also planned to furnish essentially the same system without the table so that there will be available a drive-transducer package containing servomotor, control equipment, gear box, mechanical revolution counter and position dial, and manual control potentiometer for attachment to standard machines. This console will contain relays for 15 on-off functions.

The means for generating the magnetic-tape pulse data is particularly interesting. During recording, the magnetic-tape drive speed is reduced to one-quarter playback speed to minimize the effect of operator inefficiency. After setting the table at a reference point on the workpiece, the operator manipulates a control potentiometer on the machine table, Figure 16.3. This causes the tape to start, and at the same time the table moves in a direction depending on how far it is turned. Table motion in 0.001 in. is displayed on the counter indicator. The table is run until the correct reading is obtained and then the pot is centered. This stops the table and the tape, and auxiliary commands can be recorded.

The speed-control switch selects either a high or low speed range over which the pot has control. High speed can be used for approach and low speed for final positioning. If the two-axis movements are to be recorded simultaneously (so that playback positioning will occur simultaneously) then two operators are required, one for each axis. While it is apparent that continuous

contouring can also be done, the problem of coordinating axis motions is a severe one.

Input tape format

The recorded information medium is seven-channel, ½-in.-wide magnetic tape. In the original system, four of the channels store the motion in each direction for each of the two axes; one stops the table during drilling; one controls the machine quill; and the last channel rewinds the tape automatically when a part is finished. Normal tape speed is 24 in. per sec, and at the maximum machine feed rate recording density is 175 pulses per inch. Each pulse represents 0.0002 in. of table travel, which means that the system is counting pulses at a rate of 4,166 per sec at the maximum traverse speed of 50 in. per min. Tape saturation and servo drive limitations restrict the maximum possible

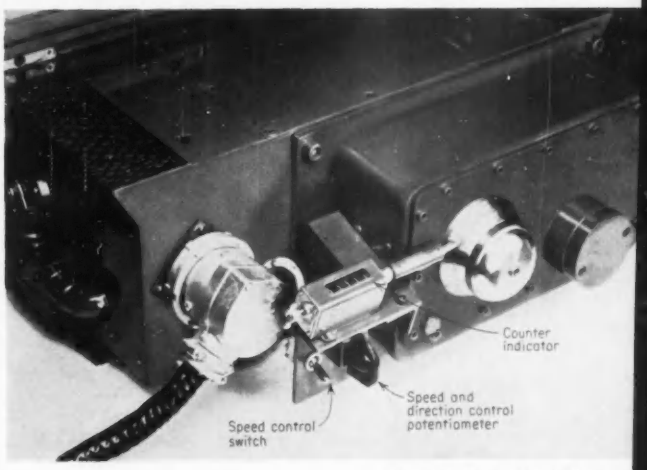


FIG. 16.3. Manual control devices for record mode.

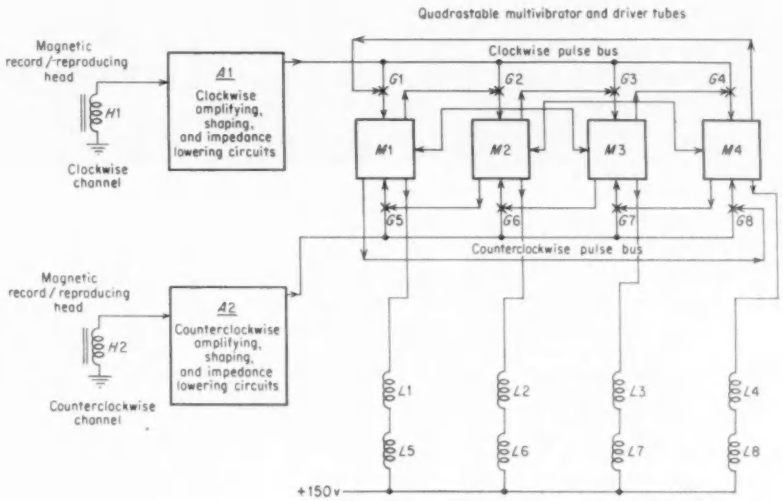
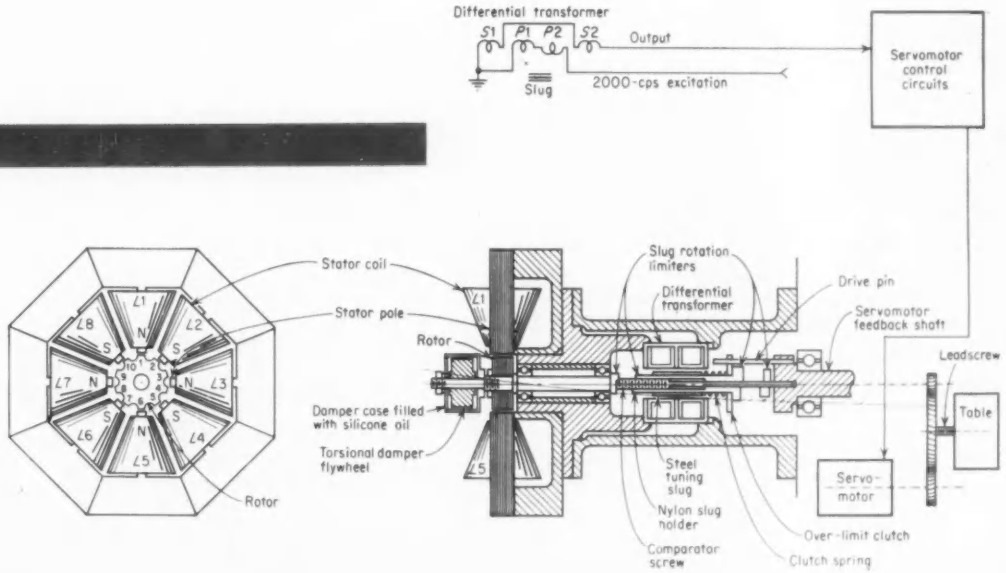


FIG. 16.4. Pulsing circuits and details of electromechanical counter.



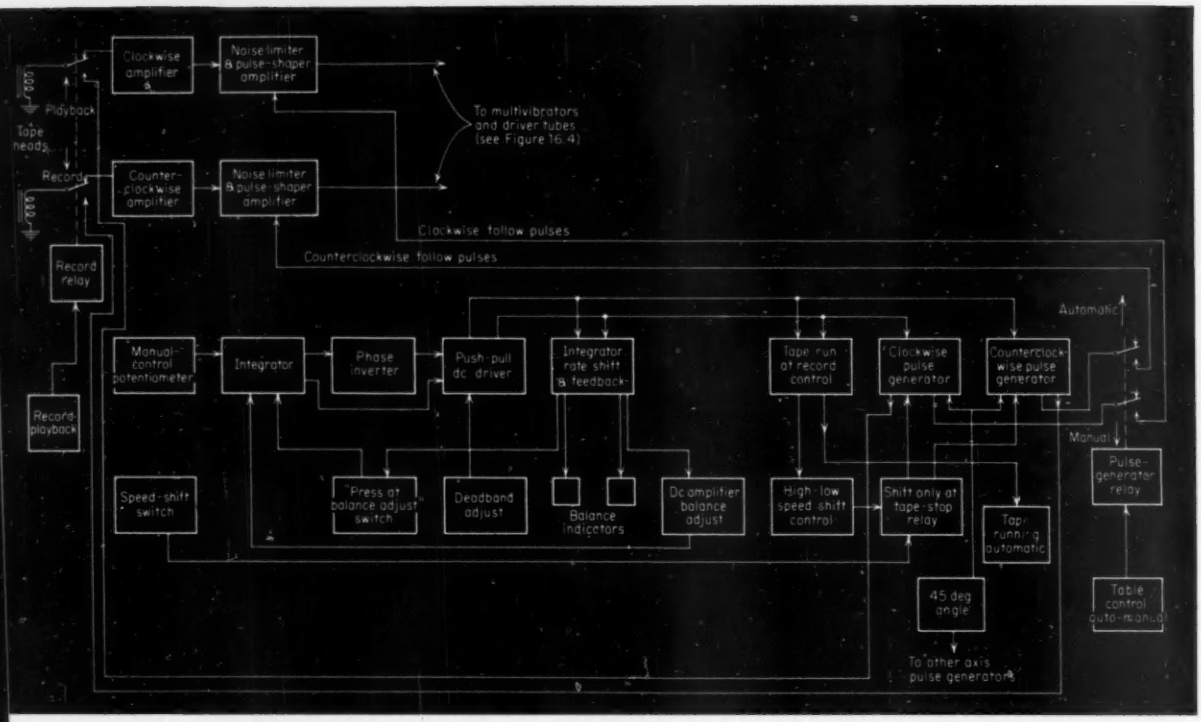


FIG. 16.5. Recording mode circuitry.

rate to 5,000 pulses per sec. The difference is safety factor. It is claimed that the system will not lose or gain more than five pulses (0.001 in. of table travel) per hour. Factory tests have shown the error to be nil.

Basic system operation

Figure 16.4 shows the most important elements for driving and positioning one axis from pulse data recorded on magnetic tape. Other equipment is required for controlling the magnetic tape reading-writing and transport mechanisms and for recording pulse data.

The unique item is the combination low-power stepping motor and linear differential transformer, which together form a pulse counting position transducer and comparator. This system is similar to the Teller Digitork system, except that the stepping motor in this case is an instrument and not the power element.

As the opposite sets of stator-pole windings (*L*1-*L*5, *L*2-*L*6, etc.) are pulsed in turn, the rotor poles are pulled around under successive stator-pole pairs in such a manner that the rotor moves through 1/40 rev per pulse. This rotation moves the steel tuning slug axially via the comparator screw and unbalances the differential transformer. The unbalance signal from the transformer is amplified in the servomotor control circuits and drives the servomotor in the proper direction to recenter the tuning slug in the differential transformer via the pin-drive mechanism. In turn, the lead-screw moves through 1/1,000 rev, causing the table to move 0.0002 in. With a high-gain differential transformer amplifier circuit, the slug will stay almost exactly centered in the transformer up to the maximum pulsing rates, so that table motion will accurately follow the input pulse train. Overlimit devices are included to prevent damage if either the stepping motor or servomotor should move while the other is deenergized. Hunting is reduced by the viscous fluid damper.

The pulses for energizing the stator windings are generated in the multivibrator and driver tube circuitry, also shown in Figure 16.4. Clockwise or counterclockwise pulses are read from the tape and conditioned in either A1 or A2. The pulses are then gated so that the driver tubes fire in the order *M*1, *M*2, *M*3, *M*4 if the pulses are read from the CW channel, or in the order *M*4, *M*3, *M*2, *M*1 if read from the CCW channel. These pulse sequences cause the stepping-motor rotor to rotate in the corresponding direction.

Recording mode

In the recording mode, pulses generated by variable-frequency pulse generators run the table through the first-piece sequence of operations and at the same time are recorded on tape. Additional pieces can be machined as described above.

Figure 16.5 shows the recording circuitry. To record, the record relay is switched to its downward *Record* position, and the pulse-generator relay is switched to its downward *Manual* position. Displacing the manual-control potentiometer one direction or the other from its zero position causes an output from one stage of the push-pull dc driver. This determines which pulse generator operates and the frequency being generated. These pulses (either CW or CCW) are recorded on tape via the record relay, and drive the table through the pulse-generator relay and the noise limiter and pulse-shaper amplifiers. The speed-shift switch selects one of two frequency output bands, depending on the desired traverse rate at a particular portion of the recording cycle. The 45-deg-angle connection synchronizes the pulse rate for 45-deg milling.

FIG. 17.1.
Micro-Positioner
on a radial drill.

System

17

MICRO-POSITIONER CORP.

While not strictly numerically controlled, the Micro-Positioner two-axis table and control console accomplishes essentially numerical control in a simple manner. Point positions are recorded by indenting a ¾-in.-wide steel tape stretched along each axis, Figure 17.1. The table is initially positioned, either manually or under power, by either referring to a direct-reading decimal counter connected to the leadscrew or to a master part fastened to the work-table. When a proper position is reached, a solenoid-operated punch conically indents the tape. Slowdown and stop precision switches automatically sense indentation location during playback. Development work was started in 1954. To-date, 30 tables have been built and put to work in the aircraft, automotive, and farm equipment manufacturing industries.

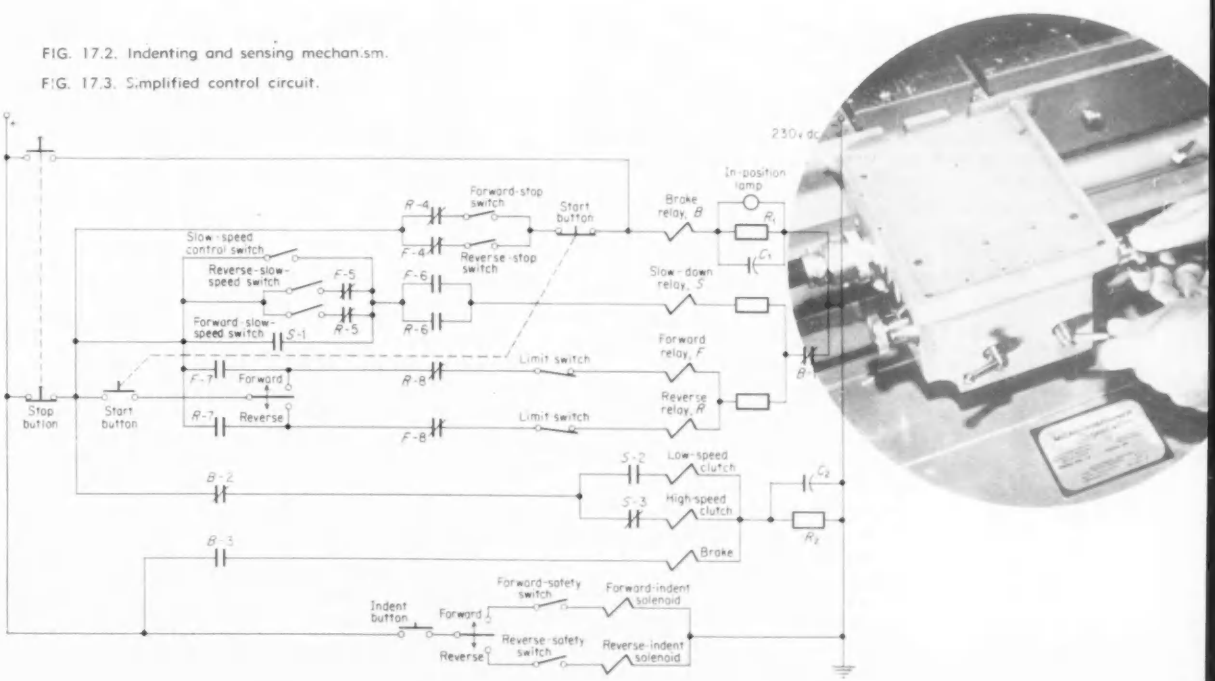
The table will repeat positions within 0.001 in. Table travel is 18 x 14 in., driven by ¼-hp ac motors through high-speed and low-speed clutches and gears at a rapid traverse speed of 90 in. per min and an approach speed of 6 in. per min. The time required to move to a point 1 in. distance in X and Y is less than 2 sec, and maximum travel takes less than 12 sec.

When moving in one direction along one axis, physical limitations make it impossible to record indentations closer together than the width of the punch tip. However, there are two sets of solenoid punches and sensing switches on each axis (one indents an upper track and the other a lower track), and by scanning the tape in one direction and then the other, points can be recorded as close together as 0.001 in. if desired. The fact that there are two channels of information, one being scanned as the table is moved in one direction and the second when the table is reversed, makes some degree of optimum sequencing possible. By deciding whether a particular hole is to be recorded on the upper or lower channel, the operator can choose the half of the scanning cycle in which the hole will actually be machined.

No vacuum tubes are required, and only four relays

FIG. 17.2. Indenting and sensing mechanism.

FIG. 17.3. Simplified control circuit.



are used per axis. All electrical equipment meets JIC specifications, which is unusual for this type equipment.

Indenting assembly

The indenting and sensing devices are in a housing attached to the table, Figure 17.2. The tape passes through the housing, and two micro-dials and two clamping levers are visible, one of each for each direction of travel along one axis. To record a position, the table is moved to the correct position by referring to the thousandth's counter. Then the proper clamp is loosened and the micro-dial is rotated until an assembly containing the slowdown and stop sensing switches moves out of the way of the indenting solenoid. The procedure also closes a safety switch, which is included to prevent indenting the tape accidentally. Finally, the assembly is reclamped and the solenoid energized to record an indentation.

When all of the positions for one direction of travel have been recorded, the switch assembly is moved back into playback position and the machine can be run through its cycle, stopping accurately at each previously recorded indentation. In the event that all of the points on one axis are shifted relative to the table (for example, if a new workpiece is not clamped in exactly the same position as the last) the micro-dials can be used to make this nulling adjustment prior to playback. In addition, the tape can be removed from the machine, stored, and used again later. A preset torque nut makes sure that the same pull is applied to the tape each time.

The electrical circuit

Figure 17.3 shows a simplified circuit for one axis. The indentation circuit is at the bottom, together with the forward and reverse safety switches that prevent accidental indentation. When the start button is pressed the correct motor direction is selected (depending on whether forward or reverse switch is closed) and the high-speed clutch is energized. When the slow-speed switch hits the first indentation, the high-speed clutch is deenergized and the low-speed clutch energized. When the stop switch, in its turn, hits the indentation, the low-speed clutch is deenergized and the brake is applied. Machining can then proceed.

It is essential to the design that the brake relay and the brake and clutch coils operate rapidly and with a high degree of repeatability. The brake relay coil and the clutch and brake coils normally operate on 90 and 115 volts, respectively, and the dropping resistors R_1 and R_2 are selected to yield these voltages. However, during transients, the shunting capacitors C_1 and C_2 apply full 230 volts across these coils, improving their transient response. With this technique, line voltage variations do not affect brake or clutch operating time.

System

18 ADVANCE INDUSTRIES, INC.

Rated as one of the fastest (150 ft per min) systems, the Advance control is being actively marketed by the Jones & Lamson Machine Co. Incorporated in a table and base assembly, the unit is obtainable either separately or complete with a drill head such as the Cincinnati-Bickford model pictured in Figure 18.1. Price of the unit as shown is $25,000 to $30,000—including positioning table, drill head, tape reader and control unit. The "bare" control, without tape reader but with two output shafts and completely packaged for industrial use, is obtainable from Advance Industries.

At the speed quoted, positioning accuracy is plus or minus 0.001 in. with repeatability of plus or minus 0.0005 in. On a typical workpiece with an average hole spacing of 3 in., the positioning rate is slightly better than 1 sec per hole. Table travel is 12 x 20 in. The control is easily programmed to permit selective sequencing—the table can be moved through a cycle of operations going from hole to hole in any order, including or omitting particular holes at will. This is an advantage when the holes in a given piece are of different sizes or require a variety of operations, such as drilling, tapping, reaming, and countersinking. In such cases, the selective-sequencing provision eliminates the need for frequent tool changing.

System operation

The input medium is 4-in. Mylar tape having a capacity of 32 channels, only 26 of which are presently used. Each row on the tape carries number data in binary-coded decimal form for one position along one axis. Four channels are assigned to each of the five dimension digits. Additional channels are assigned for designating X or Y, start and reset; and four channels are reserved for switching the control-panel lamps that instruct the operator.

The tape is read by a Binotrol (Barnes Engineering Co.) unit. Note from Figure 18.1 that this reader and all of the remaining control apparatus can be mounted directly on the machine. The reader supplies five sets of binary voltage signals to a relay matrix, where they are decoded into conventional decimal form. There are ten electrical leads from each of the five banks in the matrix. Which lead is energized in any group depends on the corresponding position code on the tape.

The buffer storage section indicated on the block diagram, Figure 18.2, consists of a group of ten stepping switches representing a five-digit decimal number in each axis. Each stepping switch is wired to a bank in the decoding matrix and homes to the energized lead.

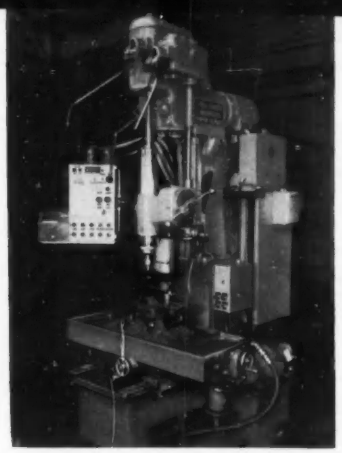
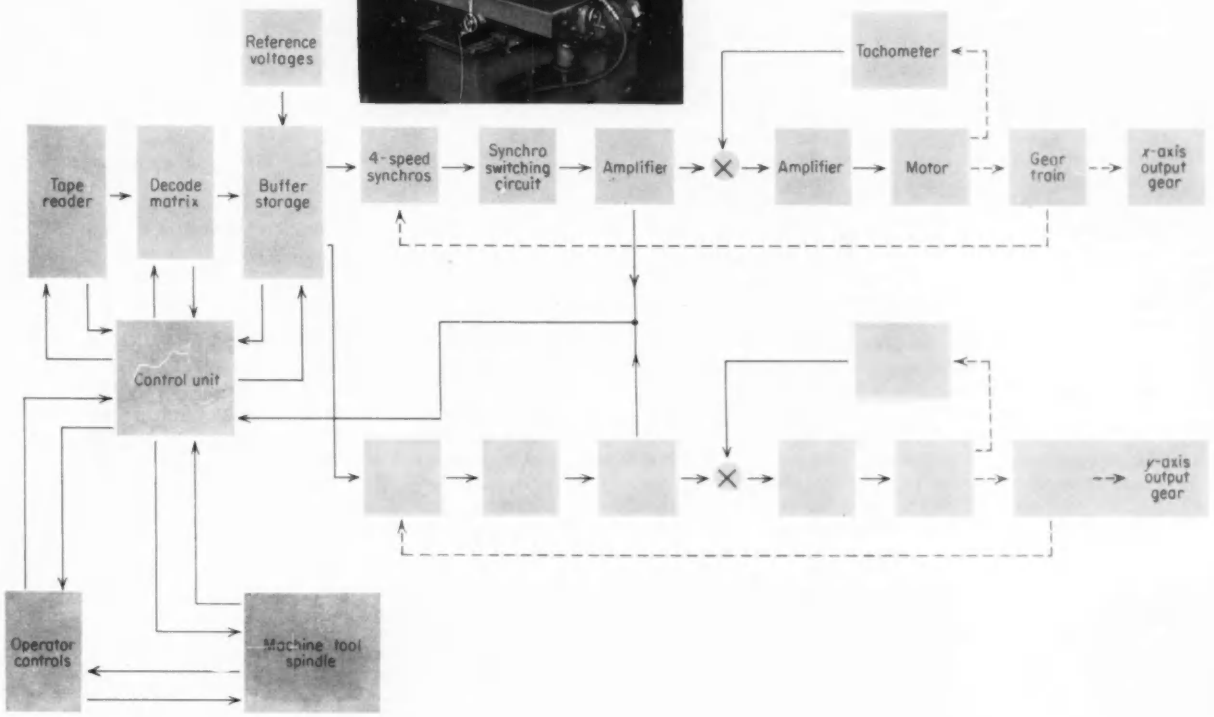


FIG. 18.1. Jones & Lamson positioning table with Cincinnati-Bickford drill.

FIG. 18.2. Block diagram of Advance positioning control.



In addition to their storage function, the stepping switches also serve as digital-to-analog converters. They select voltages from tapped transformers for later transmittal to the stators of the feedback synchros. The magnitudes of the stator voltages are so calculated that the output of the rotor winding is nulled when the synchro shaft is turned to the position demanded by the tape data.

Overlapping

Four synchros associated with the leadscrew for each axis are geared to provide the following ranges:

coarse synchro—1 rev per 100 in.
medium synchro—1 rev per 10 in.
medium-fine synchro—1 rev per 1 in.
fine synchro—1 rev per 0.1 in.

The accuracy of the system stems from the fact that each individual synchro provides a resolution of 1 out of 100, while the input signals need have a resolution of only 1 out of 10. To explain, consider the fact that there are only ten possible transformer voltages (one each for the digits 0 through 9) that are available for application to the stator of the medium synchro. If, for example, the medium synchro is to control a change in axis position from 11.600 in. to 12.400 in., a new signal of, say 2 volts, is applied to its stator windings from the ten-digit stepping switch. An error voltage now appears across the rotor winding and the servo begins to drive the slide.

It is necessary for the medium synchro to control movement of the slide until its rotor voltage is nulled, indicating that the slide has passed the 12.000-in. marker—at which point control will be turned over to the medium-fine synchro. Under ordinary conditions, therefore, the detecting circuit would have to read "no null" at 11.999 in. while accurately sensing a null at 12.000 in. It is impractical to design null detectors of such sensitivity—hence it is possible that the medium synchro will cut out somewhere before the 12.000-in. marker is reached. This redundancy is, of course, a potential source of error.

To overcome redundancy and to permit the use of null detectors of practical sensitivity, an overlapping technique has been adopted. This consists of applying a bias voltage to the rotor winding of each synchro. The bias voltages are obtained from additional tapped transformers which are scanned by the same stepping switches previously described. Thus, each synchro receives two distinct signals: stator voltages from its own

stepping switch and a rotor bias voltage from the stepping switch for the next less-significant digit.

The bias voltage is positive or negative, depending on the direction of movement along the axis. In the case cited above, the bias is positive. It is supplied from the stepping switch for the medium fine synchro and is proportional to the value of the third digit (4) of the new position. Now, as the slide moves from 11.600 in., the bias voltage prevents the detector from "seeing" a null anywhere near 11.999 in., although the true voltage induced in the rotor winding may actually be zero. Therefore, the medium synchro remains active well past the 12.000-in. point and until the 12.400-in. marker is approached. Actually, it can be switched out anywhere past 12.000 in. so that the spread between 12.000 and 12.400 in. becomes a buffer zone.

This one-digit overlap on the synchros permits use of a simple synchro-switching system in the servo amplifiers. The system incorporates nonlinear switching diodes, Figure 18.3, which present a high impedance to the coarser synchro output signal when this signal becomes significantly less than that of the finer synchro. The switching system then operates so as to present at the input of the servo amplifier the coarsest synchro output having an amplitude over a predetermined amount. The amplifier supplies power for rotating the leadscrew and the synchros as needed to reduce the signal to zero. The value of the present switching point is so chosen that it will not allow ambiguities to exist in the nulling process. As the system approaches null, the servo amplifier input is switched from the coarsest synchro to the next coarsest, all the way down the line until the finest synchro is in command. The system then comes to rest.

Drive servo

The X- and Y-axis movements are hydraulically powered under control of a unique servo valve. Figure 18.4 is a schematic of the positioning control which consists of the four feedback synchros, a differential valve, a servomotor and a precision leadscrew coupled to the table through a nut. The leadscrew does not actually transfer positioning force, but is used only to measure table movement and to shift the valve spool.

At the start of a positioning cycle the servomotor is energized, exerting torque on the leadscrew. The reaction of forces causes the leadscrew to be displaced axially with respect to the nut. The leadscrew is attached to the spool of the servo valve, which is accordingly displaced a corresponding amount. Shifting of the spool ports oil under pressure to the power cylinder in such a way as to move the table in a follow-up direction. The direction of displacement of the valve spool is dependent on the direction of rotation of the servomotor. Thus, by controlling the operation of this servomotor, tape commands also control valve actuation and saddle movement. The use of a hydraulic servo of this type relieves the precision leadscrew from any significant load, thus reducing the possibility of wear, windup, backlash, etc. The system is sensitive to leadscrew movements on the order of 0.0001 in.

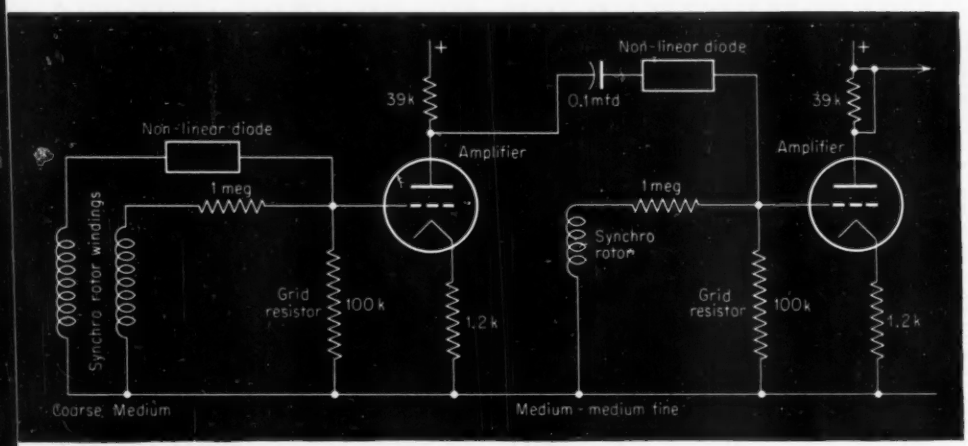


FIG. 18.3. A portion of synchro switching circuit. Output of triode at right is passed to similar circuit for fine synchro.

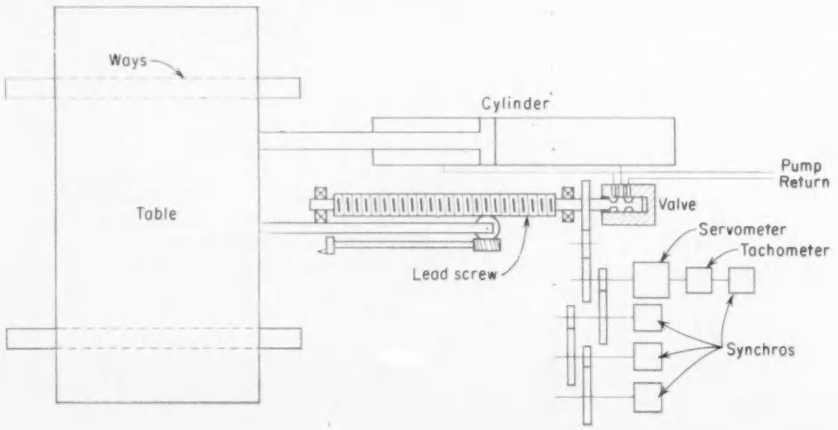


FIG. 18.4. Schematic drawing of position-control system.

FIG. 19.1. Tape-preparation unit, control console, and table.

System

19

ELECTRONIC CONTROL SYSTEMS, INC.

The ECS Digimatic Model 202 point-positioning system includes a punched-tape preparation unit, control console, and two-axis positioning table for use on either new or used high-quality machines, Figure 19.1. Tape preparation is particularly fast with this system. Although the tape code is a modified binary-coded decimal, conventional decimal information can be entered into the desk-calculator-type input unit. All positioning data and auxiliary commands for one axis of one point are entered into the calculator keyboard, then the tape is punched. Punching accuracy can be checked by referring to the adding-machine tape, printed simultaneously. Up to 18 auxiliary-function contact closures are available for use, for example, in automatically selecting one spindle on a turret drill.

An unusual feature of this mostly digital system is the absolute-position transducing subsystem, which is part analog and part digital, yielding a resolution of 0.001 in. and an accuracy of 0.0002 in. Magnetic hysteresis clutch actuators driven by constant-speed 1/15-hp ac motors contribute to high positioning rates. The maximum traverse speed is 100 in. per min, and average positioning time from hole to hole is about 2 sec (of which 0.8 sec is consumed in reading the X and Y tape blocks). The table can be accelerated from zero to maximum speed in 100 millisec.

Table travel is 14 x 18 in. The table is mounted on low-friction ball-bearing ways and is driven by a preloaded ball-bearing leadscrew which has a maximum lead error of 0.0005 in. for full travel in either direction. Way locks hold the table during machining. The control console is 24 x 24 x 48 in. high and contains about 12 tubes and 40 relays. Maintenance is simplified by easily replaced modules.

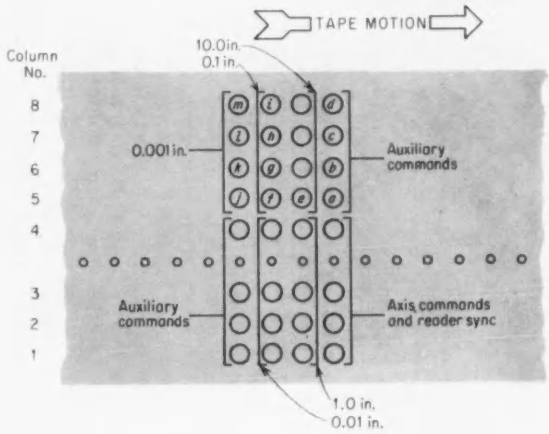
Overall system operation

In this system, Figure 19.2, everything except the position transducers, way locks, stabilizing tachometers, and actuating equipment is time-shared between the two axes, so that the positioning of the axes is sequential rather than simultaneous. A block of tape information is read a line at a time and stored in a relay storage register. From the register, the coded information indicating auxiliary functions to be performed is transferred to the auxiliary-function storage. The information indicating whether the position data applies to the X or Y axis is passed to the X-Y indicator, which actuates the X-Y selector switches to connect in the transducers and actuating devices in the axis under control and to maintain way-braking on the other axis. The storage register, in turn, receives the axis-position data.

The input position information, corresponding to the three most significant decimal decades (tens, units and tenths) of the five decades under control, is compared with the output of a multi-track, brush-type position encoder attached to the leadscrew. This digital portion of the transducing and comparison system generates only a polarity (or direction of travel) signal, and not a signal proportional to error magnitude. Thus

FIG. 19.2. Simplified block diagram.

FIG. 19.3. Typical tape field for X or Y axis.



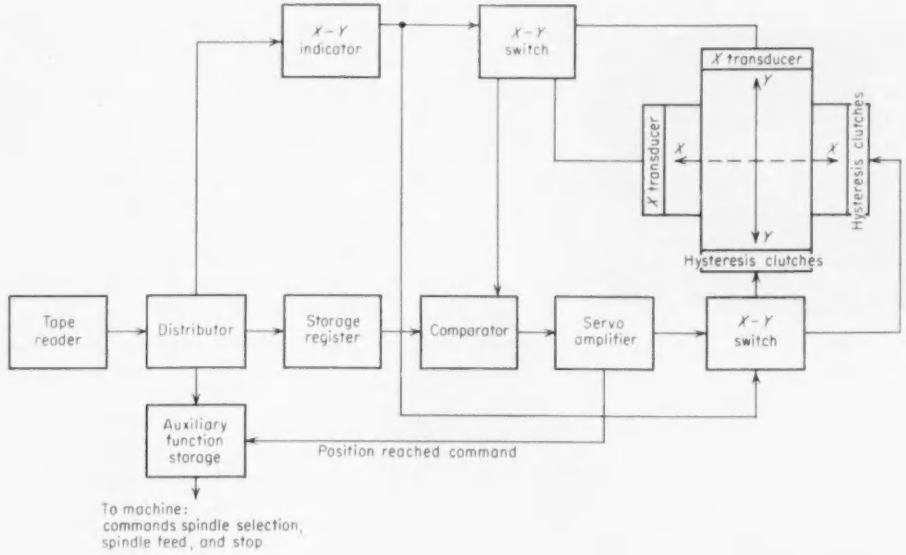
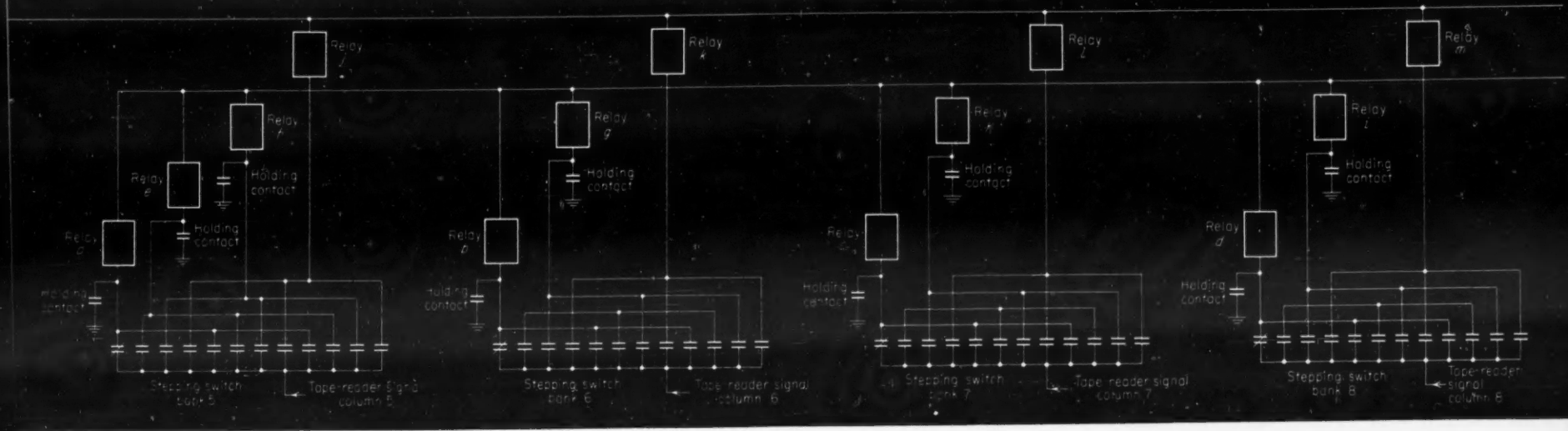


FIG. 19.4. Portion of relay storage register.



any digital error will deliver a saturating coarse error signal to the servo amplifier, causing the output element of the hysteresis clutch and the leadscrew to run at maximum traverse speed in the proper direction. When the table is within 0.02 in. of the called-for position, control is switched to the analog portion of the transducer-comparator system, which assumes command for the two least-significant decades. Here a resolver, operating in a phase-shifting comparison network, accurately measures leadscrew position to within 0.0002 in. in the last turn of leadscrew travel. The fine error signal generated during this analog portion of the positioning cycle is of the proper polarity and is proportional in magnitude to leadscrew angular error. Thus the servo amplifier operates in its linear region during this time. Because of the digital-analog combination, there are two separate portions to the transducer/comparison/storage-register network for each axis.

When the two axes are in their final position, a signal is transmitted from the in-position relay in the servo amplifier, initiating machine operations.

Input tape and storage register

Figure 19.3 shows an information block for either an X or Y position as recorded on standard eight-hole, 1-in.-wide tape. Two of these blocks in succession completely define a point and the auxiliary functions that must be performed at the point. When a sequence of positions lies along one axis, however, only one of the blocks is required per point. Note that one four-hole group is used for axis specification and reader synchronization, two four-hole groups for auxiliary commands, and five four-hole groups for the five decades of binary-coded decimal information required to determine hole position in one axis.

Figure 19.4 shows a typical portion of the relay storage required to store the information read from the tape a line at a time. This will read columns 5, 6, 7, and 8 of the tape. When the first row of information enters the reader, the stepping switch is automatically stepped to the point where the proper contacts are closed to place relays a, *b*, c, and *d* (auxiliary command relays) in the circuit. These relays are energized or not, depending on whether there is a hole in the corresponding lettered location on the tape. The energized relays are held in this state by the holding contacts. When the first row has been read, the tape reader and stepping switch advance simultaneously. Only relay e is controlled by the next row because of the limited table travel. This procedure continues until the entire tape block is stored. Note that the first three rows of relays—typified by relays a, e, and *f*—are held in by holding contacts (if energized) while the last row (relays *j*, *k*, *l*, and *m*) is held in through the reader contacts directly, since the tape does not advance again until this block of information is used.

Contacts on the storage relays a through *m* set up the proper auxiliary commands and the proper command signals in the comparison circuits. In the case of digital decoder feedback, the proper code is one that matches the one used on the decoder discs. In the analog portion, the relay combinations select outputs from tapped transformers that will generate a phase-modulated signal corresponding to resolver output at the final desired position.

System

20 FERRANTI, LTD.

All the work by Ferranti, Ltd. on point-to-point positioning has been a by-product of its development of a continuous contouring system. Out of this development came the optical diffraction grating measuring device and the servomechanism of the point-to-point system. The latter has been applied to a small drilling machine, Figure 20.1; a special installation is being designed for a six-head drilling machine for heat exchanger plates.

Its unique feature is the use of the diffraction grating for measurement. This not only renders the system free from friction and wear, and makes the effect of dust or scratches on the gratings negligible, but since the information obtained from the grating is the result of integration over a large number of lines, it permits small gaps to be tolerated in end-to-end lengths of grating.

The basic system

A length of optical diffraction grating carrying a line structure with a precisely known number of lines ruled per inch is the heart of the measuring system. The direction of these lines is at right angles to the length of the grating. Superimposing two sections of the grat-

FIG. 20.1. Simple drilling machine fitted with diffraction grating positioning control.

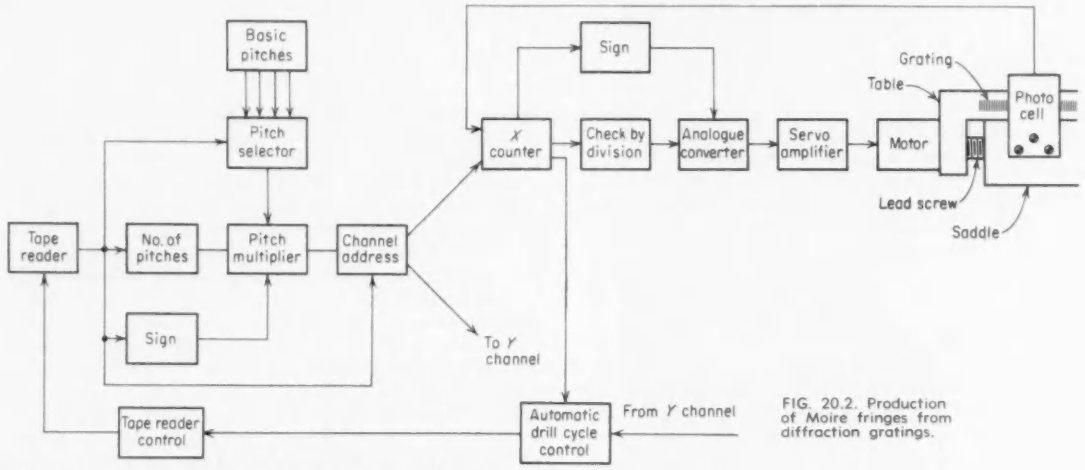


FIG. 20.2. Production of Moire fringes from diffraction gratings.

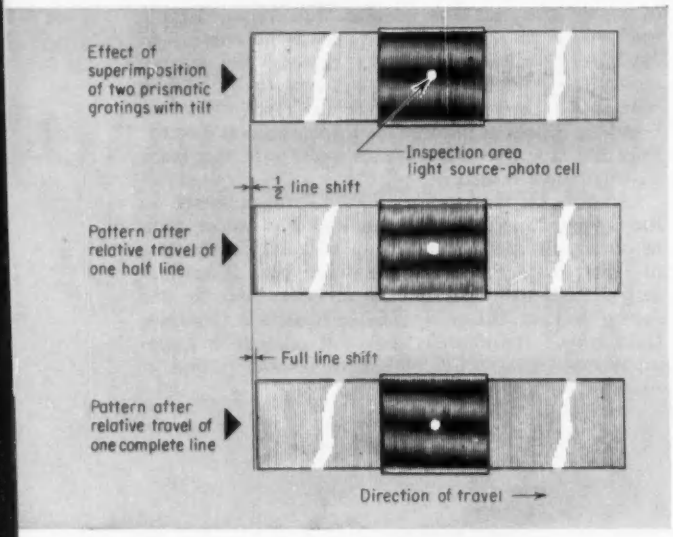


FIG. 20.3. Basic schematic of positioning application to special drilling machine.

ing so that one is tilted slightly with respect to the other (i.e., so that integrated interference effects caused by the angular intersection of the individual lines on each grating result) produces a Moire fringe pattern with an approximately sinusoidal intensity distribution. When one grating is moved with respect to the other at right angles to its line structure, this fringe pattern moves at right angles to grating motion, Figure 20.2.

The sense of the pattern movement depends on the direction of relative travel of the gratings. A relative travel of one line width on the gratings will cause a complete cycle of light and darkness of the interference pattern to pass the point examined. The number of lines per inch on the grating can vary from 500 up to 5,000, and with photoelectric pickoff devices generating a digital output of two pulses per grating line, accuracies of 0.0001 in. can be produced. To discriminate direction of movement, two points on the pattern, separated by an odd number of wavelengths, are inspected, and the directional information is obtained from the output of this two-phase system.

The drive units operating the leadscrews were also originally designed for continuous contouring applications, but are being applied for positioning work. Designed for spindle horsepowers up to 20 hp, these three-phase, 400-cps, induction-types deliver 0.7 hp at 10,000 rpm. The motor drives the leadscrew through a backlash-loaded standard gearbox to give an output shaft speed of 100 rpm at peak power. Magnetic drum brakes are fitted to the motor to act as slide clamps when the motor is de-energized.

Applications

Figure 20.3 shows the basics of the system and illustrates its application to a special drilling machine designed for heat exchanger plates. In this machine all input instructions are given in terms of the basic pitch between holes; to cover the types of work involved, four basic pitch choices can be selected from the control console. The drilling head carries six spindles separated by distances corresponding to the basic pitch multiples. Both the table position and drill selection instructions are prepared on standard five-channel teleprinter tape, the instructions being of standard length to allow for automatic checking. An instruction such as

$$XA + 03\ YC - 12\ Z101100$$

signifies a movement of three A pitches positively in the X direction, 12 C pitches negatively in the Y direction, and the selection of drills 1, 3, and 4 once this position has been reached. The taped information of the required position is read by a cassette loading reversible version of the Ferranti high-speed tape reader and is generated in binary form and fed to the X and Y reversible counters. For self-checking, the binary forms of both the required and actual position information are arranged to be N times the actual value. A continual check of the divisibility of the counter output by N makes sure that all the logic and counting portions of the circuit are operational.

The final analog signal drives the 400-cps servomotors via a three-phase magnetic amplifier.

An earlier, experimental application of the system to a simple drilling machine is shown in Figure 20.1. Spindle speed and feed-rate can be set on the control console; longitudinal and transverse dimensions, to 0.0001 in., are set by the five-decade dial system. Unit construction is employed throughout, with the circuit cards largely standardized from forms originally developed for the continuous contouring application.

System

21

BARNES ENGINEERING CO.

The Binotrol positioning control is one of a very few units that employs conventional binary numbers throughout. In comparison with binary-coded decimal notation, the pure binary system requires fewer digits to express a given decimal dimension. Use of binary numbers, therefore, makes it possible to store more data within a given area of tape. An even greater benefit is that the fewer digits lead to design economies throughout the control—requiring, for example, fewer reading contacts, buffer storage relays and electrical connections. One shortcoming is that tapes are somewhat harder to prepare, because conversion from decimal to binary involves use of a table.

Barnes markets the Binotrol development as a complete control package to machine manufacturers, one of the earliest being Jones & Lamson Machine Co., which used it in a turret lathe application. Per-axis cost of the control is about $3,000 plus accessories. A complete 10 x 18 in. automatic positioning table, similar to that in Figure 21.1, is available at a price under $10,000. Accuracy is plus or minus 0.001 in. at a table speed of 50 in. per min. Barnes also supplies the tape reader and punch to other control manufacturers.

Tape input

Storage medium is a special 4⅞-in. Mylar tape. Each row on the tape contains 32 columns, accommodating two 15-digit binary numbers representing sufficient storage capacity for X and Y dimensions of from 0 to 32.767 in. The basic control can be extended to three or more axes by using a buffer storage or by adopting sequential (any two axes at a time) positioning. In applications requiring extensive auxiliary control, one row is assigned to each axis, freeing 17 channnels for data on addresses, on feed, spindle, and traverse speeds, and on dwell time, interlocks, and parity check.

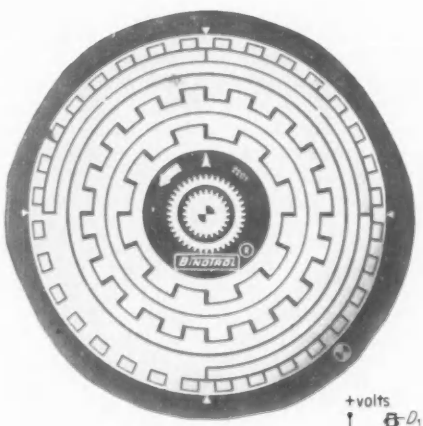
The feedback device is a four-disc printed circuit digitizer geared to the machine leadscrew. On the discs, Figure 21.2, there is a total of 15 bands, each consisting of alternating areas of energized and non-energized conductive material. The pattern of such areas conforms to the binary numbering system.

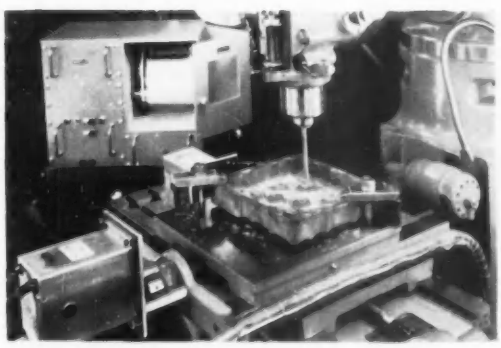
Comparison network

An ingenious relay network, Figure 21.3, contributes to the simplicity of the Barnes system. Here the 15-digit input and feedback numbers are compared without conversion of any kind. The error signals from this comparator are applied directly to the control relay of the drive motor or, as in the case of the J&L lathe, to a hydraulic servo valve.*

In Figure 21.3, the D relays are connected to the digitizer brushes and the T relays to the tape-reading fingers. There are a pair of these relays assigned to each digit. Comparison is made one digit at a time, beginning with the most significant (D_1 and T_1). Under the conditions shown, all relays are deenergized, indicating that there is no number on the tape and that the machine slide is at zero position. A circuit is complete from + voltage to the stop relay. When the tape is indexed, a T relay will be energized wherever a hole appears. The transfer of the relays activates the forward relay. As the table moves, the digitizer brushes begin to encounter live segments, thus energizing those D relays paired with an energized T relay. In this way the stop circuit remakes when input and output correspond.

* Valve described in section on Advance Industries, Inc.





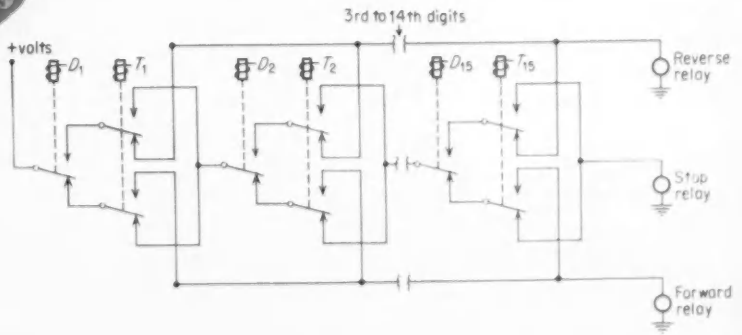


FIG. 21.1. Tape reader is integral with control console for the Barnes positioning table.

FIG. 21.2. One face of binary-coded disc. Printed gears permit accurate alignment with actual gears in measuring unit.

FIG. 21.3. Schematic diagram of comparison circuit.

FIG. 22.1. Packaged drill rig, control, and tape reader and separate tape-preparation unit.

System

22 LABORATORY FOR ELECTRONICS, INC.

LFE developed the system shown in Figure 22.1 as a research project to determine the feasibility of getting into the machine tool control business and at the same time to provide an economical means of drilling printed circuit boards for internal use. The system consists of a two-axis positioning table, automatic drill head, control unit, and tape reader in one structure, plus a separate desk-calculator-type tape-preparation unit. This unit is not for sale since it is strictly an experimental model; however, LFE is interested in supplying machine builders with semi-custom-designed positioning systems consisting of a programming unit, power servos, and position feedback transducers for incorporation in specific new machine tools. The number of controlled axes and auxiliary functions (either on-off or modulating) can be varied to suit the application.

This system is completely digital, with table position measured in the form of an absolute digital code. Since the unit shown in Figure 22.1 was developed for drilling printed circuit boards, the data system uses fractions of an inch rather than decimal increments: resolution is $\frac{1}{128}$ in. and it is accurate to within 1/128 in. Although the punched-tape input medium uses binary-coded fractions of an inch, tape preparation is simple—the tape punch converts the positioning information in inches and fractions and the auxiliary commands into tape code. As in the ECS system, rapid positioning is achieved by using magnetic hysteresis clutches to connect constant speed motors to the table drive mechanism. Average time from point to point—including tape reading, positioning, and drilling—is about 1 sec, the fastest of any of the systems. Maximum table travel in this prototype unit is 8 x 16 in.

Input tape coding

Figure 22.2 shows a field that completely specifies one point on $\frac{7}{8}$-in.-wide eight-hole tape. Binary-coded integral inches and fractions of inches for the long and short axes are grouped in four separate tape areas. Three other specific areas are used to transmit machine sequencing and tape synchronizing commands. A hole in column *H* stops the machine. Since the tape is read a line at a time, relay buffer storage is required. For other applications, the input coding could be modified to handle decimal rather than fractional information, and other rows could be added to the field without changing the basic system logic.

Overall system operation

After the tape is inserted in the reader and the power is turned on there is a 20-sec pause for tube warm-up caused by thermal time-delay relays in the main circuits. When the thermal relays time-out, a stop light comes on and the start button can be pressed.

The first instruction detected by the tape reader is the coded signal in area *E*, indicating that a valid block of information is to be stored in buffer storage. When the complete block of data is stored (as indicated by a coded signal in area G), the sequential control portion of the data-handling system takes over and releases the positional information to the continuous parallel subtractors, Figure 22.3. Only static elements—transistors and diodes—are used in the parallel subtractors. Note that there is no time-sharing of any of the circuitry, so that positioning takes place simultaneously in both axes.

The continuous digital output of the subtractors (difference between coded desired position and coded actual position) is applied to a resistance-matrix digital-to-analog converter which produces an output voltage proportional to the actual error in machine position. This voltage is in turn applied to the dc servo amplifier which drives the reversible-hysteresis-clutch/gearing combination. In this case, hysteresis clutch output drives the table through a leadscrew-linkage arrangement instead of directly through a leadscrew and nut. The long-axis linkage can be seen in Figure 22.1.

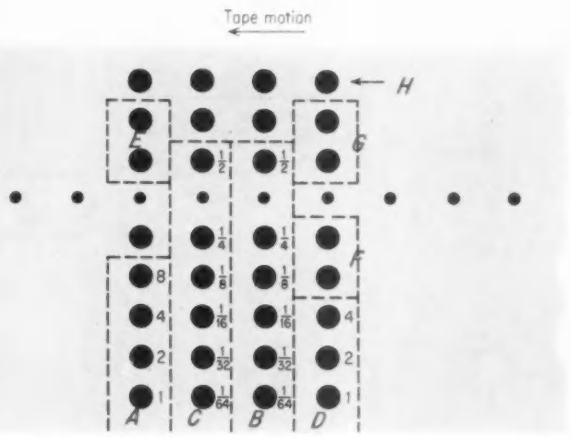
The position feedback transducer is a Gray-coded analog-to-digital shaft-position encoder, driven by an anti-backlash pinion running on a precision rack. The mechanical ratio is such that the least converter increment corresponds to $\frac{1}{64}$-in. table travel. As in other systems where table position is measured from a precision rack independent of the power system, backlash, compliance, and other power leadscrew inaccuracies are not important.

The positioning operation continues until the output voltage from the subtractor reaches zero and remains in a steady-state condition for 40 millisec. At this time the drill head is actuated. Although the table is not actually locked during machining, viscous braking is obtained from the high-gradient tachometers. The tachometers are also used for stabilization during the driving period, since the hysteresis clutches exhibit no inherent damping.

As the drill head starts its downward travel, the sequence control releases the stored data for the hole being drilled and advances the tape reader to store the information on the next hole to be drilled. When the hole has been drilled and the drill head returns to its up position, the table automatically moves to the next position and the cycle repeats.

Parallel subtractor

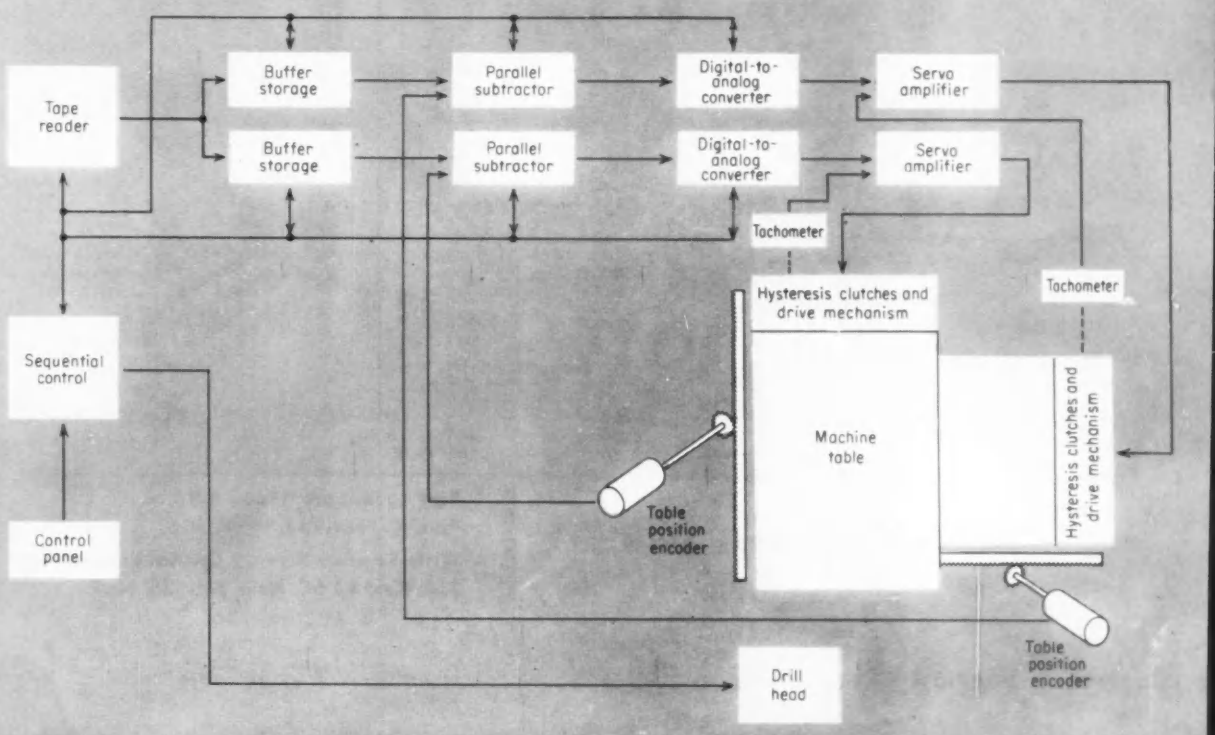
One reason this system is so fast is because it uses a high-speed parallel subtractor as a comparator. Figure 22.4 shows a three-digit Gray-code converter and parallel subtractor in block form, and the accompanying table lists the code manipulations. Since the com-

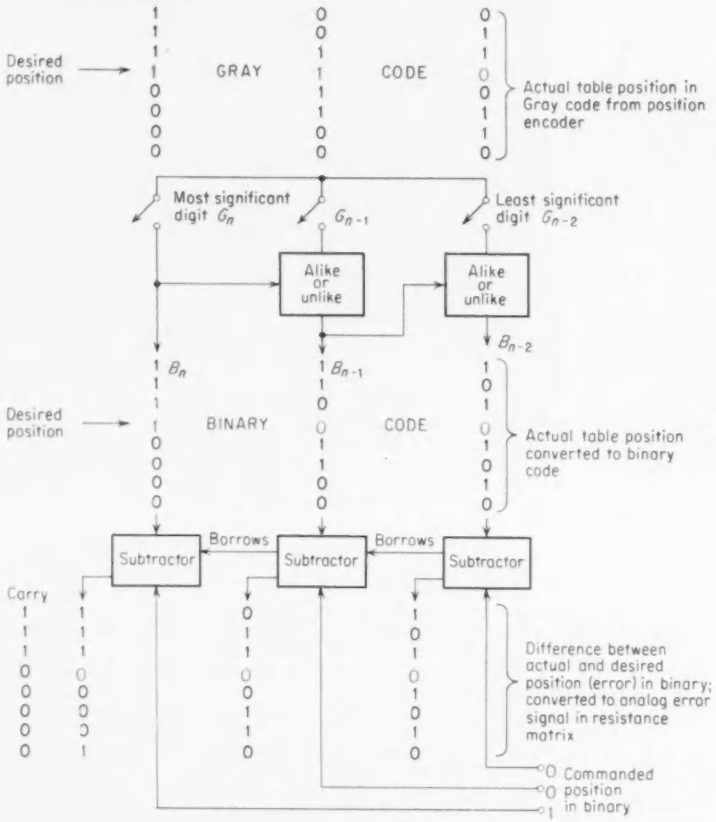


A- Sum of holes punched in this area indicate inches of travel along long axis.
B- Sum of holes punched in this area indicate fractional inches of travel along long axis.
C- Sum of holes punched in this area indicate fractional inches of travel along short axis.
D- Sum of holes punched in this area indicate inches of travel along short axis.
E- Holes punched in this area indicate that data punched in this block is to be stored in buffer register.
F- Holes punched in this area command machining sequence.
G- Holes mean row four of block is being read, information is stored, servos are to be released to position table, and start storing new information.
H- Holes in this column means stop machine.

FIG. 22.2. Tape field contains all information for one point.

FIG. 22.3. Simplified system schematic.





F.G. 22.4. Code converter and parallel subtractor.

manded input position from the tape is in binary code, and the actual position from the disc encoder is in Gray code, the disc code must be converted to binary before the two positions can be compared.

In converting from Gray to binary, the most significant binary digit, B_n, is always the same as the most significant Gray digit, G_n. The next most significant binary digit, B_{n-1}, is determined by comparing the next most significant Gray digit, G_{n-1}, with B_n. If they are alike (both 1's or 0's) then B_{n-1} is 0; if they are unlike then B_{n-1} is 1. As can be seen by examining the converted numbers in the table and on the figure, this same rule is followed from most significant to least significant digit until the complete number is converted. (Note that the columns of codes on the figure are inverted with respect to the columns in the table.) The figure shows the schematic circuitry required to make this conversion. The most significant digit passes through directly, while the succeeding Gray digits are compared with the immediately preceding binary digits in the "alike or unlike" units. The result of the comparison determines the corresponding binary digit.

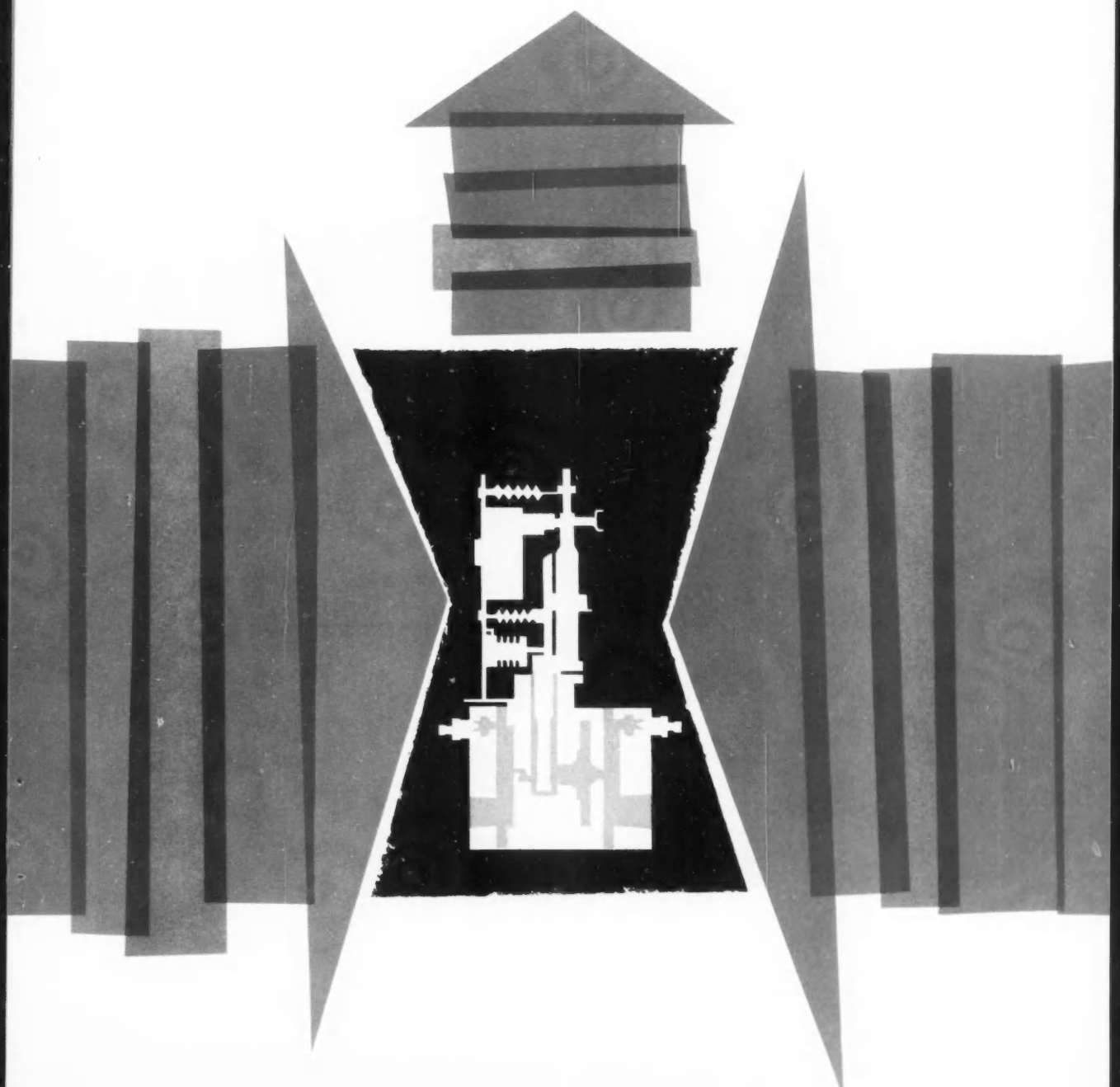
Now the actual table position in binary-coded form must be compared with the commanded position to determine the magnitude and direction of the error. The actual position is subtracted from the binary-coded commanded position (100 in this case) in the subtractor and the difference is converted to a proportional analog signal in the resistance matrix and applied to the servo amplifier. This works fine as long as the commanded position is greater than the actual position, but difficulties are encountered when the reverse is true. For example, subtracting 101 from 100 yields 111, but there is a carry of 1. In other words, what actually happens is that 1000 is added to 101, 100 is subtracted from this total, and then 1000 is subtracted to obtain the actual number. This is shown in the fourth column of the table. However, note that as the actual position gets greater and greater than the commanded position, the difference gets smaller instead of larger as it should (111, 110, 101). To correct this, the complement is taken, as shown in the fifth column. But this complement is still 1 less than the correct error code, so that one must be added to each coded error quantity.

This procedure is done automatically in the subtractor and resistance matrix; if there is a carry from the most significant digit, the complement of the error code is taken and 1 is added to it to yield the proper error. The carry signal also energizes the reverse clutch to drive the table in the proper direction.

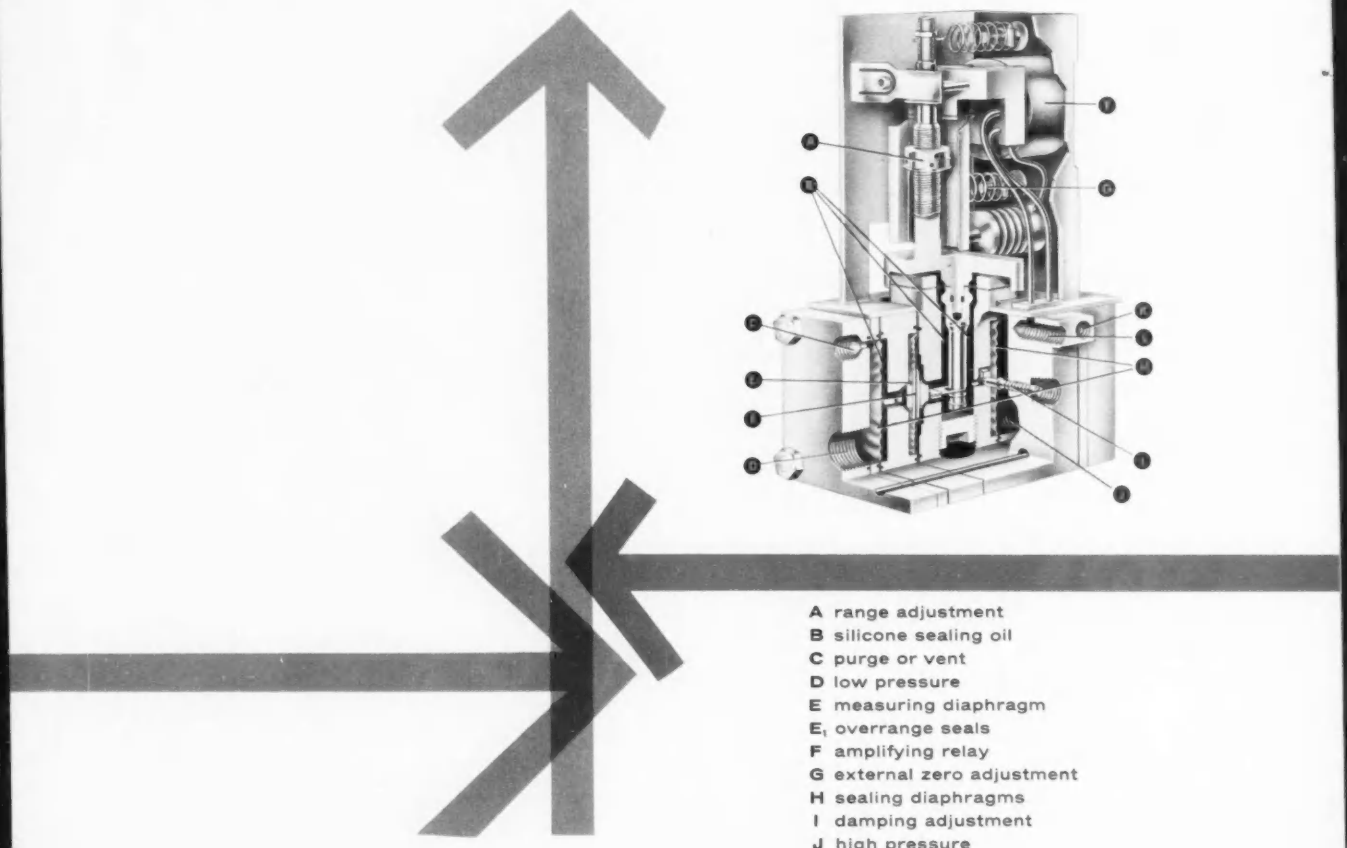
PARALLEL SUBTRACTOR CODING

Actual table position in Gray code	Actual table position in binary code	Commanded position in binary	Difference between actual and commanded (error)	Complement of difference when actual is greater than commanded	Complement plus one for correct error
000	000	100	100		
001	001	100	011		
011	010	100	010		
010	011	100	001		
110	100	100	000		
111	101	100	111 (−1000)	−000	−001
101	110	100	110 (−1000)	−001	−010
100	111	100	101 (−1000)	−010	−101

new approach to **dp** transmitting



new **dp** transmitter tames pulsating flows with adjustable internal damping



A range adjustment
B silicone sealing oil
C purge or vent
D low pressure
E measuring diaphragm
E_1 overrange seals
F amplifying relay
G external zero adjustment
H sealing diaphragms
I damping adjustment
J high pressure
K output pressure
L air supply

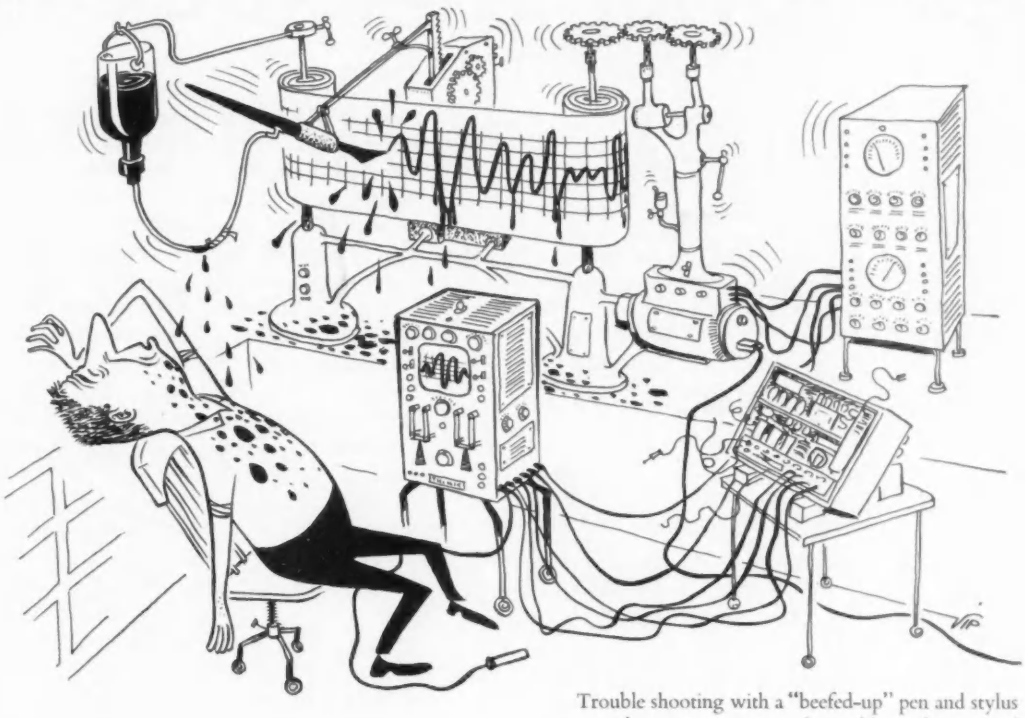
Not long ago, F & P engineers set about building a better differential pressure transmitter. Their main purpose: to obtain dp transmitting of the highest accuracy and dependability by providing adjustable internal damping, maintenance-free operation, and superior calibration stability. Their design approach: keep the process fluid out of the measuring system.

An examination of the illustration above reveals how the input pressures, applied to the sealing diaphragms, are transmitted to the measuring diaphragm by silicone sealing oil. Adjustable internal damping is achieved by a needle valve which restricts the flow of sealing oil. This ensures fast response to full changes in differential pressure, yet isolates the force balance system from extraneous impulses. Pulsating flows present no problems for this transmitter. And since the needle valve is in the clean sealing oil, its operation is trouble free, regardless of the amount of damping required.

The unique and revolutionary design of this new dp transmitter makes it well worth investigating. You'll find that F & P's totally enclosed measuring system has many other important advantages not treated here. These transmitters are now available on six week delivery schedules. Contact the F & P field engineer nearest you for a demonstration or evaluation unit, or write for Catalog 10B1465. Fischer & Porter Company, 300 County Line Road, Hatboro, Pa. In Canada, write Fischer & Porter (Canada) Ltd., 2700 Jane Street, Toronto, Ontario.

FP FISCHER & PORTER COMPANY • *complete process instrumentation*

How to Save Man Days in Research and Testing Involving Transients—**No. 5** *of a series*



PROBLEM: Trouble Shooting

Trouble shooting with a "beefed-up" pen and stylus recorder can cause as much trouble as the original malady—thereby compounding the felony. Also, conventional recorders cannot capture high-frequency transients because of comparatively slow response.

SOLUTION: The Hughes **MEMO-SCOPE® Oscilloscope** can instantly "freeze" any number of selected traces. A storage type oscilloscope, it retains displays brilliantly *until intentionally erased*. Faithful reproduction of transients is assured always...for the electron beam has no appreciable weight, as opposed to the mass of mechanical recorder movement.

HUGHES MEMO-SCOPE OSCILLOSCOPE

STORAGE TUBE—5-inch diameter Memotron® Direct Display Cathode Ray Storage Tube. Writing speed for storage: 125,000 inches per second. The optional Speed Enhancement Feature multiplies writing speed approximately four times.

OPTIONAL PREAMPLIFIER EQUIPMENT—High Sensitivity, Differential Input, Type HS/6: 1 millivolt to 50 volts per division. Dual Trace Type WB/DI/11: 10 millivolts to 50 volts per division. Four independent positions may be selected for single or double channel performance and chopped or alternate sweeps.

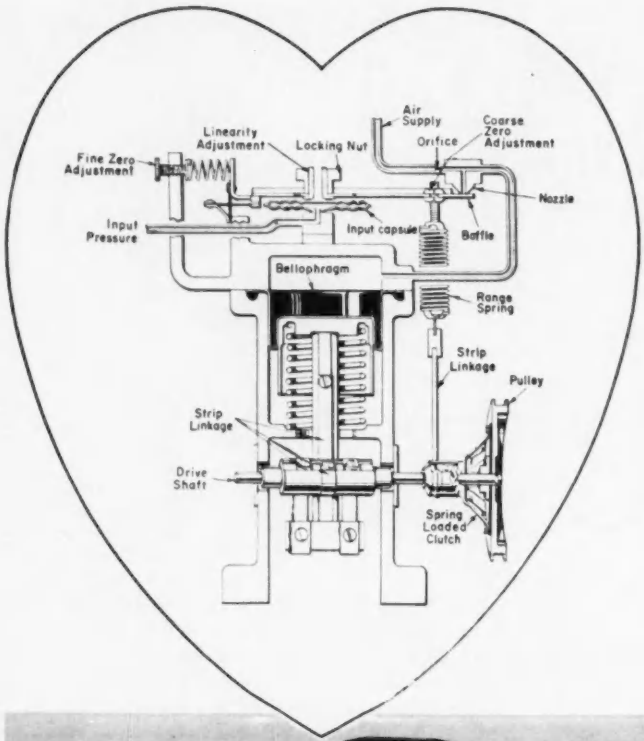
We are sure you will want to see this "transient recorder with a memory" in action. A Hughes representative in your local area will arrange a demonstration in your company. Please write now to:

HUGHES PRODUCTS MEMO-SCOPE Oscilloscope
International Airport Station, Los Angeles 45, California

Creating a new world with ELECTRONICS

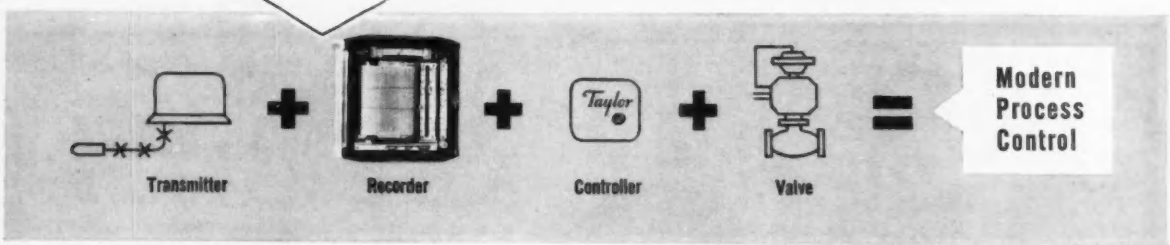
HUGHES PRODUCTS

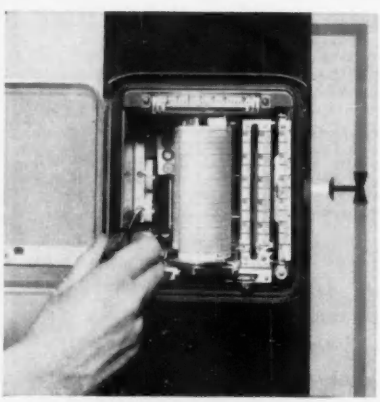
New Taylor TRANSCOPE*



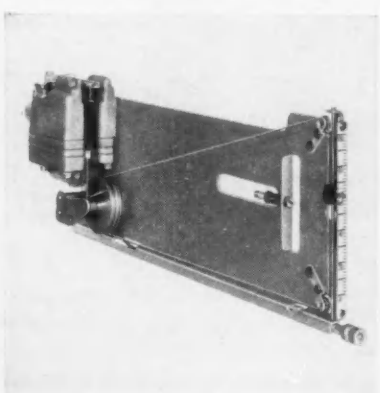
"SERVOMATIC" MOTOR assures lifetime accuracy of pen position. Transmitter signal is received and amplified by individual force balance servo-mechanisms. Efficient spring feedback and powerful longstroke pneumatic motor give *150 times greater power than normally available for pen positioning.* This means greater accuracy; less service needed. If you like servo-operated devices . . . power steering, power brakes . . . you'll want SERVOMATIC powered pens.

0.1% THRESHOLD SENSITIVITY—A NEW STANDARD OF ACCURACY. Responsiveness to transmitter output is 0.1%; and because of the very small pneumatic displacement of the input capsule, the response is practically instantaneous. You see more minute process changes, enabling you to make optimum control settings to increase yield of specification product. All servos are identical and interchangeable. Servo-pen connection is by means of cable . . . no long, jointed, flimsy links or levers. Allows perfect linear conversion from rotary motion . . . repeatability is truly amazing.

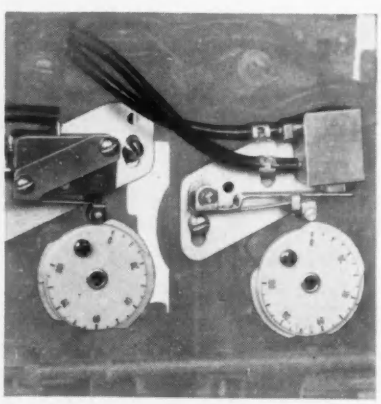




Controller Settings are made from the front while recording. Gain. reset and PRE-ACT* dials are calibrated in specific units. Eliminates blind adjustments; settings and results are seen in one-spot . . . the front of the panel.



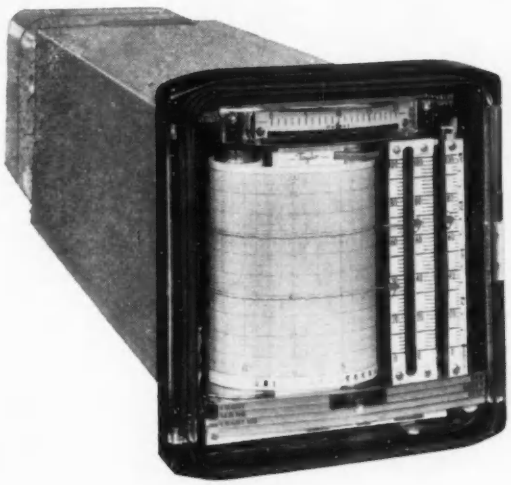
Exclusive "Set Point Transmitter" allows continuous automatic control during recorder removal. Plug-in transmitter assembly may be removed and control valve sealed in operating position. Perfect for continuous processes.



Optional Alarms. Each SERVOMATIC motor can operate either an electric or a pneumatic alarm. Each alarm can be adjusted for one high and one low, or two high, or two low operating points. Microswitch on left, air valve on right.

Recorder brings you . . .

REVOLUTIONARY ACCURACY, BIG-INSTRUMENT FEATURES



"No other recorder, regardless of size, puts so many features in so little panel space."

Front of Panel Control Settings let you make adjustments easier, quicker, and better . . . *from the front of the panel* . . . while recording! You can clearly see what you are doing, and the results, because the record is continuous.

Stays on Automatic Control while the recorder is removed for inspection. The unique Set Point Transmitter remains plugged in the case, providing continuous fully automatic control.

Complete Indicating Control Station while recorder is removed. You see the variable. There's no need to shut down the process for instrument service or adjustments. Horizontal gage at top of recorder will show either process variable or air output to valve, as desired.

Receives Three Variables to be recorded or indicated; has a Set Point Transmitter, an Automatic-to-Manual switching lever, a Cascade or process-output indicator, and many other features . . . all in a compact case.

For further information about this revolutionary new recorder, see your Taylor Field Engineer, or write for **Form No. 98282.** Taylor Instrument Companies, Rochester 1, N. Y., or Toronto, Ontario.

*Trade-Mark

MADE FOR EACH OTHER!

The Taylor TRANSCOPE Controller and Recorder are companion instruments. Together they give you new standards of process control performance . . unprecedented accuracy and adaptability. Ideal for the time constants of modern processing, exceptionally fast and responsive to adjustments, the TRANSCOPE Controller is also highly adaptable and simple to maintain. Write for **Bulletin 98278.**

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CONTROL reactors are ready in eleven sizes in both 120 and 240 volt ranges. Our unique catalog R-10 gives you complete physical and operating characteristics. It tells you, for instance, that six ampere-turns control nearly 2,000 watts in the largest size, and that only two ampere-turns are needed for the 50-watt smallest size, illustrating the extremely high gain of these units.

Want to know about cut-off ratios? CONTROL reactors run at least 40 to 1. Want to know about construction? Cutaway shows you the tough, rugged design that insures "forever" operation with no servicing or maintenance, if operation is normal.

Yes, there's a real improvement here for harassed engineering departments. Standardization means reliability and quality at a competitive price. Write for Catalog R-10 today and read all about it. *CONTROL, Dept. CE-42, Butler, Pennsylvania.*

Reliability begins with CONTROL

A DIVISION OF MAGNETICS, INC.

Yield-Tension Control Improves Draw Forming

RICHARD HUMISTON, Cyril Bath Co.

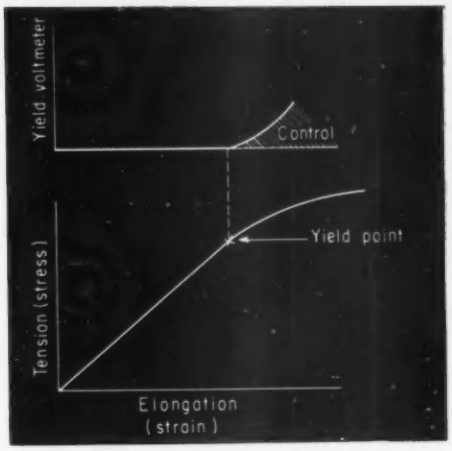


FIG. 1. Tension vs. elongation chart determines yield point of material.

In the drawing and forming of metal components, one of the problems is preventing metal fatigue and structural weakening. Strain-gage tests show that tension in the part being stretched and formed around the die varies considerably during the operation even when the hydraulic pressure on the draw-former machine is held constant. One method of overcoming these stresses utilizes a measurement of the tension in the part to control the hydraulic ram pressure.

A draw-forming machine recently delivered to the Army Ballistic Missile Agency in Huntsville, Ala., for use on the production of Jupiter missile components, incorporates such a yield tension monitor control system to eliminate overstretching or breakage in the forming process. A radial draw former delivered to Convair, will produce the basic structure for a jet transport, and also has yield-tension control.

Measurements of the tension in the workpiece are made and compared with the elongation, Figure 1. From this comparison, the yield point of the metal (i.e., the point at which forming is possible) can be determined. With the yield point known, a maximum tension level is set into the system and variation of the tension from this reference controls the hydraulic ram, and hence the elongation, to maintain the metal at its yield point.

A strain gage load cell placed between the ram and the gripper head that holds the work provides a measurement of tension, Figure 2. After amplification, the tension signal is compared with an elongation voltage obtained from a potentiometer on the hydraulic ram. (Voltmeters provide an indication of tension, elongation and yield.) When tension is applied, a manually operated control in the elongation circuit adjusts the slope factor of the voltage/elongation and voltage/tension parameters until they are equal. Below the yield point the tension voltages and the elongation voltages are proportional, equal, and opposite so that the yield voltmeter recording the difference in these voltages remains at zero. With increased tension above the yield point, the rate of change of elongation voltage is greater than the tension voltage, and deflection of the yield meter and illumination of the yield indicator lamp show the material to be ready for forming.

An off-setting control allows the operating point of the control system to be set slightly above the yield point. When the yield voltage reaches this point, a small dc motor operates a relief valve in the hydraulic ram system to reduce the power applied to the ram. The power reduction continues until the yield meter zeros and the tension in the workpiece reverts to its preset value.

A recording unit gives a graphic record of the stresses imposed on each piece during the work-forming cycle. This quality control assures that each part is formed with consistent predetermined pressures. Figure 3 is a typical record with yield tension control in operation, showing the accuracy of tension control throughout the drawing operation.

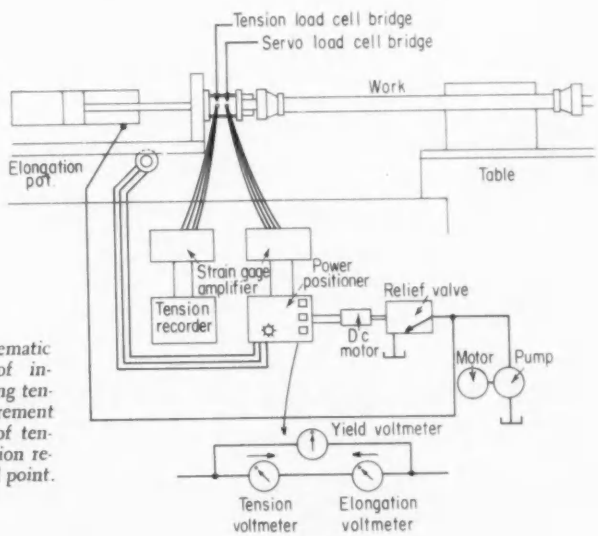
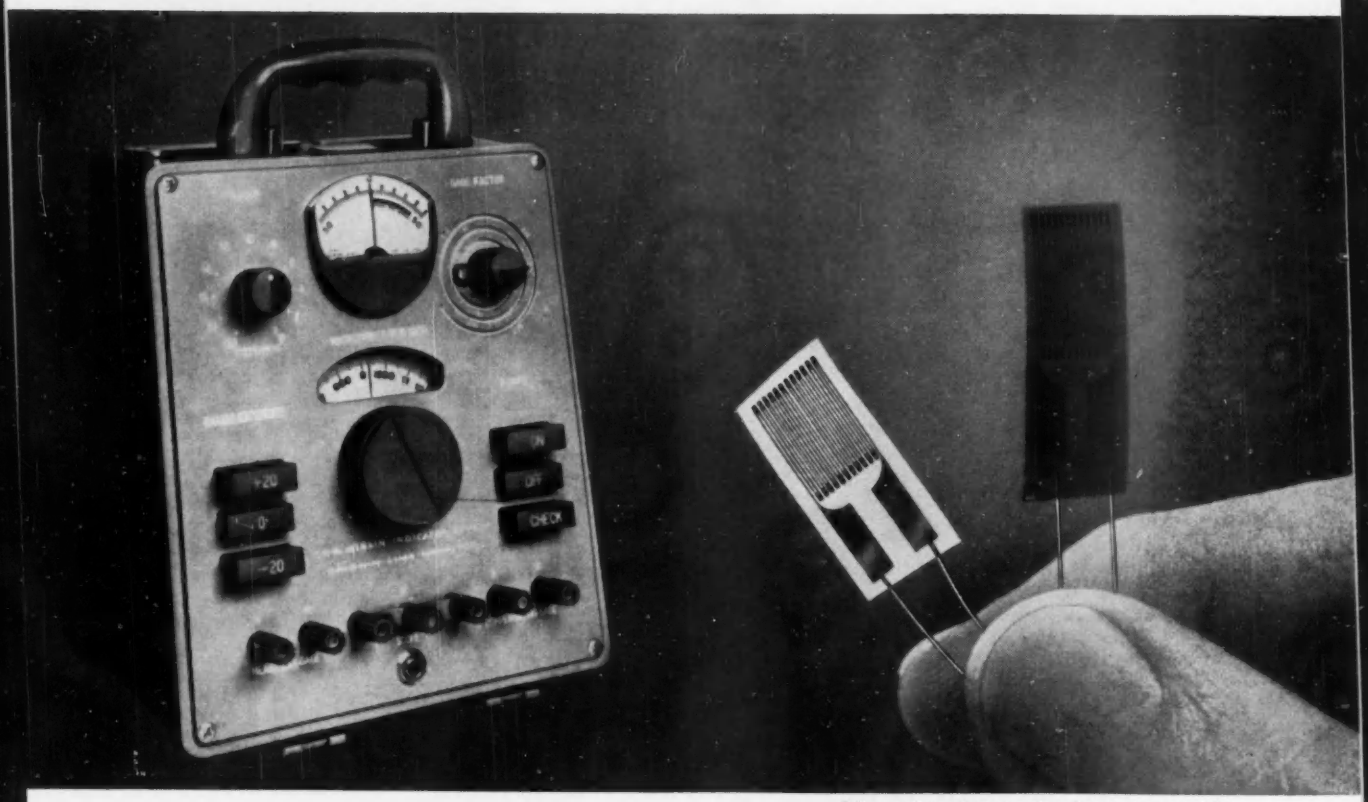


FIG. 2. Schematic shows system of indirectly controlling tension from measurement of interrelation of tension and elongation related to the yield point.

FIG. 3. Pen recorder indicates accuracy of tension control throughout drawing operation.

Newest strain-measuring equipment from Baldwin



Foil gages shown above are enlarged to twice their actual size.

NEW SR-4® strain indicator and NEW SR-4 bonded foil strain gages

Type N SR-4 Strain Indicator

This new, improved strain indicator features printed circuits and transistors, weighs one-third less than the previous model and has a smaller case. No warmup is required. In intermittent service its batteries last up to five times as long and cost two-thirds less. The legs of the case are positioned to permit tilting for improved readability. For direct readings with full external bridge, no calibration correction is required. Used as a preamplifier with standard cathode ray oscilloscope, it gives visual indication of dynamic strain with better response and in a broader range than the previous model. Frequencies up to 300 cps at amplitudes up to 3500 microinches per in. can be observed without appreciable distortion.

SR-4 Bonded Foil Strain Gages

Two new types of foil gage in ½ in. gage length, 120 ohms resistance, now make many types of stress analysis possible with new accuracy and ease. A Bakelite-bonded gage, Type FAB-2, and a quick-drying paper-and-cement-bonded gage, Type FAP-2, have marked advantages over comparable standard bonded wire strain gages. Hysteresis is now so low as to be negligible for stress analysis. Fatigue life of the paper gage matches that of comparable wire gages—that of the Bakelite gage is longer. Lateral strain sensitivity of both is down by one-half, offering new accuracy in measuring biaxial strains. The quick-drying paper gage is quick and easy to install. The Bakelite gage offers such attractive features as dependable service at 300°F or higher. It is thinner and more flexible than comparable bonded wire gages—requires no preforming for curved surfaces and is thus easier to apply. Its glass fiber filler makes it less sensitive to moisture effects.

Both new foil gages have tinned lead wires, well anchored and easy to connect. Both gages are now stock items for prompt delivery. For more information on this or other Baldwin stress analysis equipment, write to Electronics & Instrumentation Division of B-L-H, Dept. 6-B, Waltham, Mass. Or we will have a representative call on you at your request.

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SR-4® strain gages • Transducers • Testing machines

Sine-Cosine Encoders Beat Angle Encoders

In target position computations, 13-digit sine-cosine encoders provide not only accuracy equivalent to 16-digit angle encoders throughout the angular range, but also a speed-up in calculation.

WERNER I. FRANK
Electronics Corp. of America

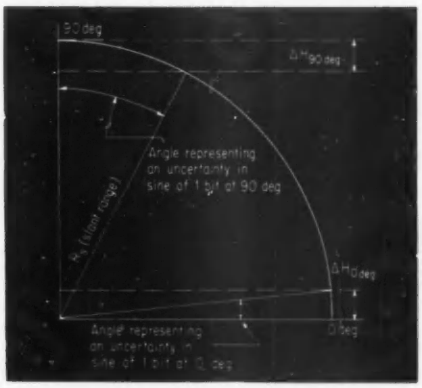


FIG. 1. Constant accuracy obtained in computed H values is irrespective of elevation angle.

Substituting sine-cosine encoders for linearly-spaced angle encoders in determining position by means of tracking radars and theodolites not only eliminates a cumbersome power series conversion, but gives the same order of accuracy with fewer digits; i.e., a 13-digit sine-cosine disc does about as well as a 16-digit linear encoder.

In the computation of a missile's path from radar data, all that is normally required is the sine and cosine of the measured angle. The linear encoder provides a reading of this angle as a binary-digit figure in terms of the angular distance traveled from an arbitrarily chosen reference radius. But then a power series conversion is required to determine the sine and cosine values, and the computer time needed for this conversion may become a serious problem in real-time data processing applications. A sine-cosine encoder provides outputs directly as the sine and cosine of the measured angle, thus eliminating the conversion.

How is it that the 13-digit sine-cosine encoder is comparable in accuracy to the 16-digit linear encoder? Principally, it is because the sine and cosine values are computed from radian measurements, whereas measurement in the linear encoder is taken with reference to the whole circle and corresponds to 2π times the equivalent radian measure. This means that a 16-digit disc measures not to within 1 part in 65,356, but only to 1 part in $65{,}356/2\pi$—approximately one part in 10,000 of a radian. Accuracy of the 13-digit sine-cosine disc, which is good to one part in 8,000, is thus directly comparable. Looking at it another way, the angle subtended by a 2^{-16} part of a circle is approximately 20 sec, comparable with that of $\sin^{-1}(2^{-13})$, which is 25 sec.

With sine-cosine encoders it is true that the sine markers are more widely spaced near 90 deg than they are at 0 deg, and that the uncertainty of one bit will thus encompass a greater angle at 90 than at 0 deg. However, this does not mean the accuracy of computation is less at greater angles. In deriving the altitude from the slant range, where

$$H = R_s \sin \phi, \quad H = \text{altitude},$$
$$R_s = \text{slant range}, \quad \phi = \text{elevation angle}$$

an uncertainty of one bit (amounting with a 13-digit disc to 2^{-13}) means that the maximum altitude error is

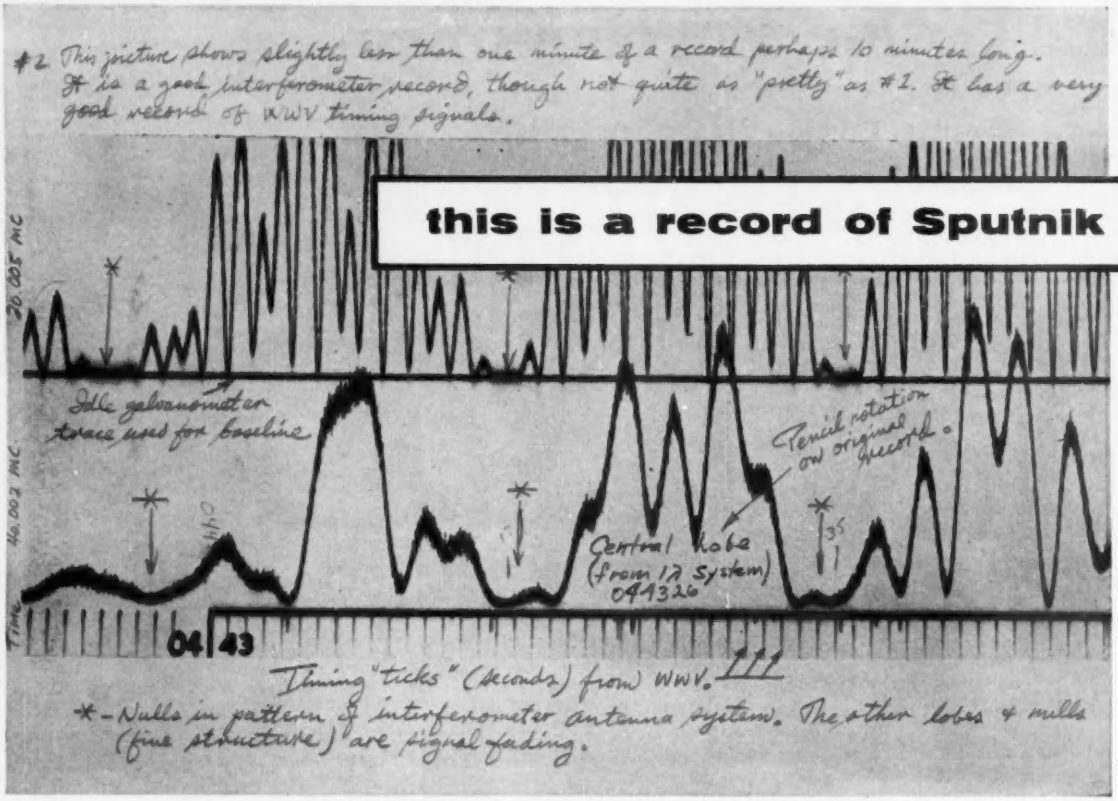
$$\Delta H = R_s \times 2^{-13}$$

regardless of where ϕ is measured, Figure 1.

Thus the accuracy of any H computation for a given slant range will be independent of the angles at which the target finds itself when the readings are taken, and uniform accuracy of computation is obtained. Corresponding relationships exist for X and Y.

The availability of commercial 13- and 14-digit sine-cosine discs, Figure 2, promises an accuracy equivalent to 16- and 17-digit linear encoders in all systems where the end product is the target space position in cartesian coordinates of X, Y and H. The elimination of the power series calculation may well make sine-cosine discs obligatory for installations with real-time calculations at high information rates.

FIG. 2. A 14-digit sine-cosine encoder disc

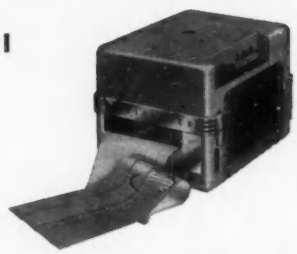


The Visicorder has charted the orbit of Sputnik I

A Model 906 Honeywell Visicorder Oscillograph wrote this record of the signals from Sputnik I for the Department of Electrical Engineering at the University of Illinois at Urbana. The marginal notes are those of Edgar Hayden, the research associate who took the record.

Interferometer-type antenna systems (2 dipole elements ⅛ wavelength above ground spaced several wavelengths along a north-south baseline) received the two signals for communications-type radio receivers. The beat oscillators generated audio output signals, a semi-conductor bridge circuit rectified them, and the d-c output, filtered by an R-C network with a time constant of about .003 seconds, was used to drive the Visicorder galvanometers directly.

The Visicorder, teamed with the interferometer antenna, quickly established a record of the orbit of Sputnik I.



The Honeywell Visicorder is the first high-frequency, high-sensitivity *direct* recording oscillograph. In laboratories and in the field everywhere, instantly-readable Visicorder records are pointing the way to new advances in product design, rocketry, computing, control, nucleonics . . . in any field where high speed variables are under study.

To record high frequency variables—and monitor them as they are recorded—use the Visicorder Oscillograph. Call your nearest Minneapolis Honeywell Industrial Sales Office for a demonstration.

Honeywell

Heiland Division

Minneapolis Honeywell Regulator Co., Heiland Division, 5200 E. Evans Ave., Denver 22, Colo. **Reference Data:** Write for Visicorder Bulletin

Moon Computer Uses Breadboard Servos in Field

One-of-a-kind servos in a finalized form for field use have been very expensive. A new approach to breadboarding makes possible field units of low cost that are rugged and have reproducible dynamics.

ALBERT S. GOODRICH
Gap Instrument Corp.

A rugged field design of a servo computer with the same dynamic characteristics as the breadboard prototype is often very difficult to develop, and always very expensive if only a few units are needed.

The Signal Corps Servomechanisms Laboratory has had many experiences with this problem. A typical one required the design and construction of two identical rate-position servos for the elevation and azimuth computations in a computer for predicting the position of the moon. The computer is part of a system which continuously points an antenna at the moon or other objects from which reflections are too small for radar tracking. Discrete orbital positions are digitally computed for as much as a year in advance for each three-minute interval and stored on punched tape. This information is converted, as required, to discrete voltages. The elevation and azimuth rate-position servos then continuously interpolate these discrete voltages to position synchro transmitters. The antenna has its own servos which repeat the transmitted positions.

A fully designed and packaged quality unit for the elevation and rate position servos would have taken months to produce. Time was important, and funds were budgeted.

A new approach was needed that would

- Produce a unit rugged enough for field service directly from time-saving breadboarding techniques
- Be reproducible in dynamic characteristics with preferably no hand adjustments.

Previous experience with similar servos indicated that it would take about 300 hours over a 9-10 week period to produce a suitable elevation servo by conventional methods. The instrument construction system developed for this problem required 35 hours and only three days.

The IC system

The new "IC system" is unique in two major respects: first, it is a modular system based on a multiplicity of fixed gear centers selected to give a wide range of ratios; second, its basic structural unit is a pair of accurately bored plates joined by aligning spacer assemblies.

The basic structural unit is a pair of matched plates which are identified throughout manufacture to the extent of indicating the inside and outside of each plate. The plates are jig-bored in sets. All holes are of the same size (0.3125 in.) with a zero negative tolerance and a positive tolerance of 0.0002 in. The matrices of the holes are located on centers 0.4167 in. apart. Errors between hole centers are not cumulative, so that over any number of hole spacings the tolerance is within plus or minus 0.0002 in. The holes serve as bearing seats and as locators for the plate spacers and component adapters; threaded bushings convert them for fastening synchro clamps and auxiliary bearings. With the parallel plate system, not only is there good rigidity, but because the gears run in class 7 instrument bear-

FIG. 1. Schematic diagram of an elevation rate-position servo used in Signal Corps moon predictor computer.

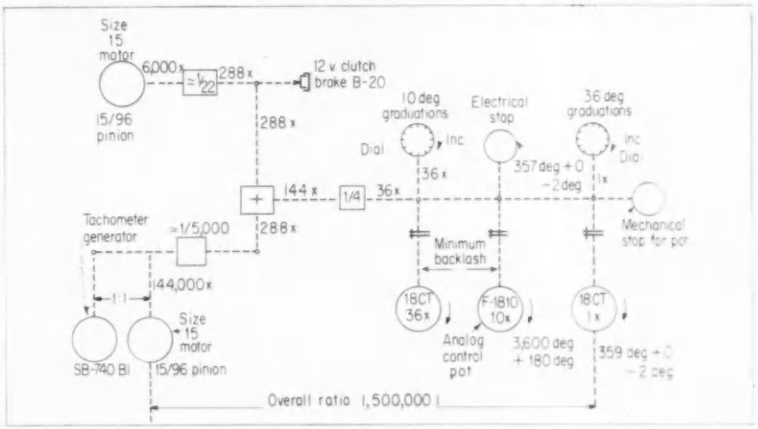
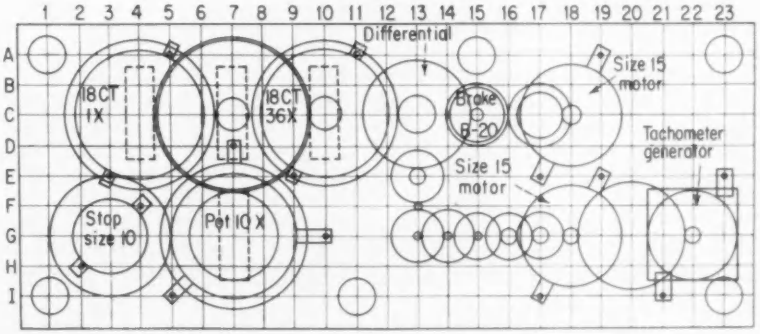
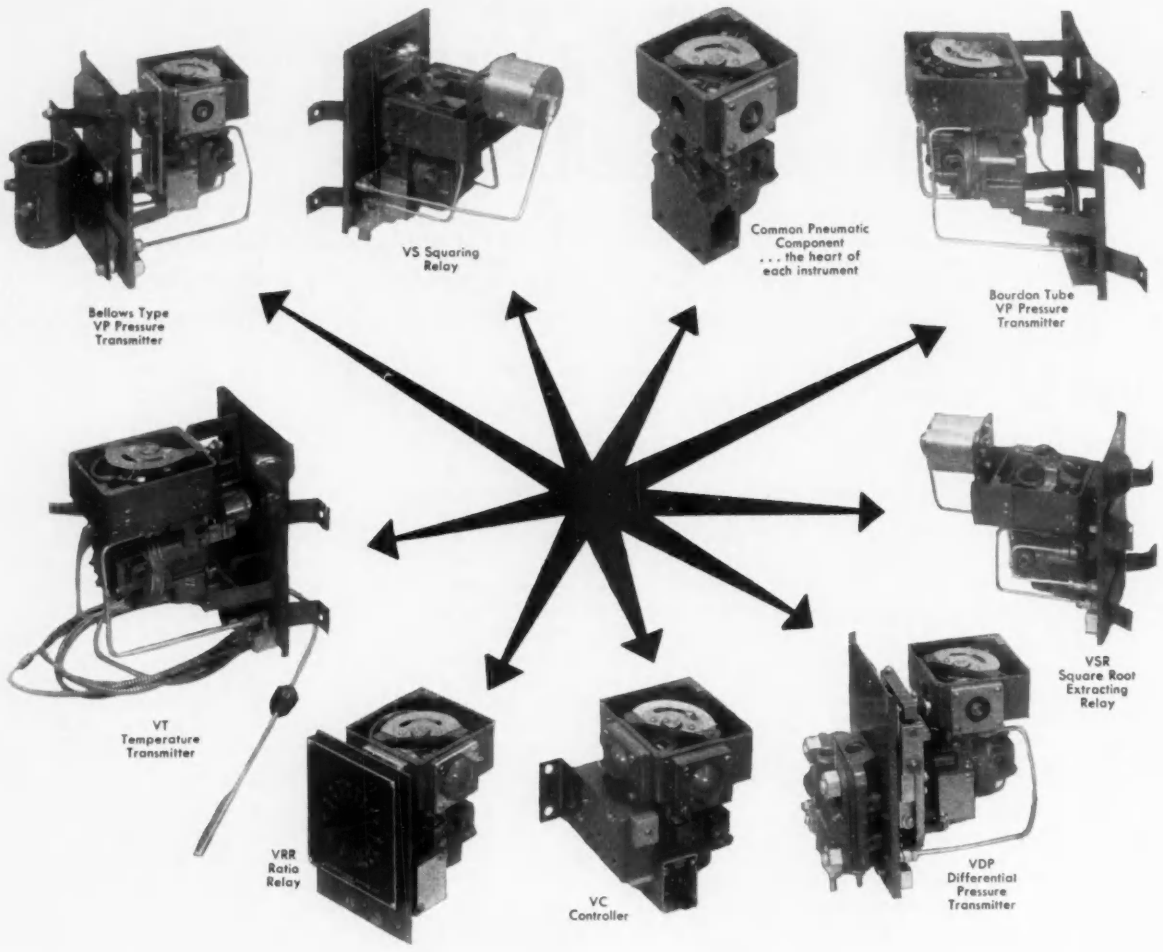


FIG. 2. The grid layout sheet shows the simplicity of layout requirements for a complex servo unit.





It's YOUR move—in ANY direction—with

Republic's New Family of Null-Balance-Vector Instruments

Here are only a few of Republic's new line of pneumatic instruments. Their sensitive, extremely accurate components are both compact and interchangeable. Their versatility is phenomenal. Consider: the Vector Series components in *each* of these instruments can be moved and *recombined in infinite variety.* They form temperature transmitters with 10-to-1 range adjustment . . . pressure transmitters of ±0.5% accuracy . . . differential pressure transmitters with 20-to-1 range adjustment . . . controllers which feature repeatable re-set rate, less than 0.05% dead band and proportional band adjustment from 2 to 500%.

The span of each instrument can be varied at will; only a screwdriver and a reference are necessary—zero need not be re-set. Republic's Null-Balance-Vector design permits full-range operation with virtually no parts motion—and virtually no wear.

This new family of pneumatic instruments was developed in a coordinated program to use the greatest possible number of common components. Because these can be interchanged, even among instruments performing entirely different functions, training and spare parts problems are greatly simplified. The versatility of Republic components is at once a challenge and an answer to imaginative engineers. A few minutes of discussion on this subject could be well worthwhile . . . and a call to your nearest Republic Sales Office will set it up at your convenience.

For detailed, descriptive folios write

REPUBLIC FLOW METERS CO.

Subsidiary of ROCKWELL MANUFACTURING COMPANY
2240 DIVERSEY PARKWAY CHICAGO 47, ILLINOIS
In Canada: Republic Flow Meters Canada, Ltd.—Toronto
Manufacturers of electronic and pneumatic instrument and control systems for utility, process and industrial applications.

ings in parallel planes, there is accurate meshing with little backlash.

In using the new system, the proposed servo, shown schematically in Figure 1 for the moon position predictor servo, is transferred to a special layout grid, as shown in Figure 2. This grid simply locates the possible bearing positions on the parallel plates. A special template can be used to draw in the standard servo components and gear pitch diameters. An elevation layout has been found unnecessary.

The choice of bearing hole centers is such that 30 gear sizes satisfy 95 percent of all servo requirements. A ratio table compiled for the system minimizes the need for calculating gear ratios. The bearing plates have been made in five sizes, all 4.5 in. wide, from 4.5 to 12 in. long. Plate spacers are made in three different lengths. Only four Allen wrenches are needed to assemble these units.

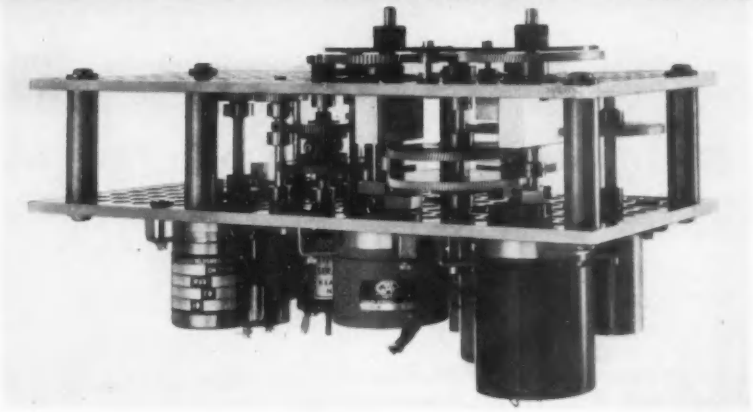


FIG. 3. The completed breadboard shows the rigidity and compactness of parallel-plate construction.

Figure 3 is a photograph of the final form of the moon prediction elevation servo. It is compact, easily reproduced, and rugged enough for field use. All components are standardized so that design and purchasing times are minimized. The parts can be salvaged for other use if the servo is no longer needed, and the grid layout serves as a permanent record from which the unit can easily be reproduced at some other time.

A New Slide Rule for Transfer Functions

J. E. VALSTAR
C. F. Braun & Co.

A continuous scale time-constant slide rule reduces the determination of the frequency response of a control system from its transfer function to a series of summations of attenuation and phase angle. Covering six decades, the slide rule is designed to handle up to 10 factors shown in the transfer function:

$$G(j\omega) = Ke^{j\omega\tau} \frac{(j\omega)^p \prod_{1}^{k} (1+j\omega\tau_a)^q}{(j\omega)^s \prod_{i+1}^{m} (1+j\omega\tau_c)^t} \times \frac{\prod_{k+1}^{l} [1 + 2\zeta_b j\omega\tau_b + (j\omega\tau_b)^2]^r}{\prod_{m+1}^{n} [1+2\zeta_d j\omega\tau_d + (j\omega\tau_d)^2]^u}$$

The rule is simply constructed of a cardboard frame with windows for ten slides at the front and the rear, Figure 1. Logarithmic time constant τ and angular frequency ω scales are marked over the six decades at the top of the frame, and the bottom frequency scale allows for accurate positioning of the hairline cursor anywhere on the rule in spite of its awkward length.

Various function slides are inserted in the windows according to the transfer function being computed. These slides are marked on the front with db amplitude ratios and on the reverse in degrees of phase shift.

Slides are available for four functions, $j\omega$ (linear db scale), $e^{j\omega}$ phase shift scale proportional to ω, $(1 + j\omega)$, and $(1 + 1/j\omega)$. A special slide of

$$= [(1/\zeta^2) - 1]^{1/2}$$

enables the conjugate complex roots

$$1 + 2\zeta j\omega\tau + (j\omega\tau)^2$$

to be determined, where $\zeta < 1$.

In operation the 3-db breakpoints of the $(1 + j\omega)$ functions are set against the appropriate value on the time-constant scale and the overall attenuation and phase determined by summing the db and phase reading on each slide under the particular value of ω being plotted.

The two conjugate roots of the factor

$$1 + 2\zeta j\omega\tau + (j\omega\tau)^2$$

are obtained by using the $(1 + j\omega)$ slide in conjunction with the special plus or minus $[(1/\zeta^2) - 1]^{\frac{1}{2}}$ slide, since expansion of the factor equals

$$\zeta^2 \left\{1 + j\left[\frac{\omega\tau}{\zeta} + \left(\frac{1}{\zeta^2} - 1\right)^{1/2}\right]\right\} \times \left\{1 + j\left[\frac{\omega\tau}{\zeta} - \left(\frac{1}{\zeta^2} - 1\right)^{1/2}\right]\right\}$$

Here both the 3-db breakpoint of the $(1 + j\omega)$ slide and the value of $[(1/\zeta^2) - 1]^{\frac{1}{2}}$ are set against τ/ζ on the time-constant scale. The reference lines on this special scale then determine how much higher or lower the dbs and angles have to be read on the $(1 + j\omega)$ slide.

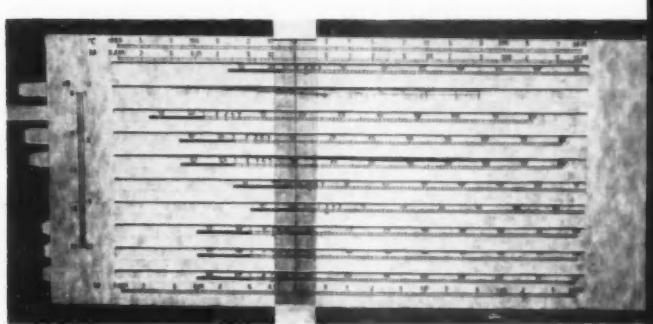


FIG. 1.

The slide rule pictured has nine $(1+j\omega)$ slides.

The tenth is a $[(1/\zeta^2)-1]^{1/2}$ slide.

Silicon Unijunction Transistor

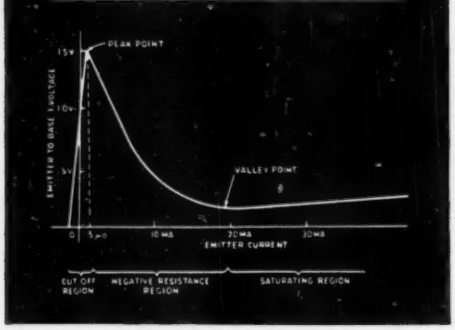
SPECIFICATIONS OF THE SIX SILICON UNIJUNCTION TYPES

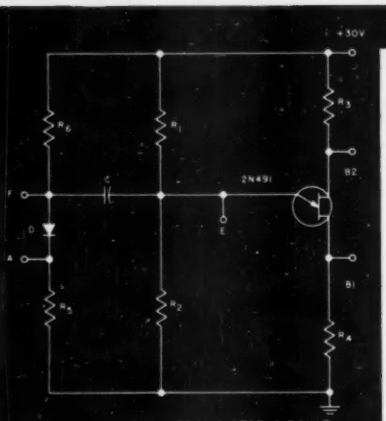
Absolute maximum ratings (25°C)

RMS power dissipation—stabilized	350 mw
RMS emitter current	50 ma
Peak emitter current	2 amps
Emitter reverse voltage	60 volts
Operating temperature range	—65°C to 150°C

Major electrical characteristics (nominal)

	2N489	490	491	492	493	494	
Interbase resistance at 25°C junction temp.	5.6	7.5	5.6	7.5	5.6	7.5	kΩ
Intrinsic standoff ratio.	.56	.56	.62	.62	.68	.68	
Modulated interbase current	12	12	12	12	12	12	ma
Emitter reverse current							
(T_J=25°C)	.07	.07	.07	.07	.07	.07	μa
(T_J=150°C)	28	28	28	28	28	28	μa





BASIC UNIJUNCTION TRANSISTOR CIRCUIT

Circuit function	Components removed from basic circuit
Pulse generator	D, R2, R5, R6
Pulse amplifier	D, R4, R6
Multivibrator	R2, R4
One-shot multivibrator	R4
Flip-flop	C, D, R4, R5, R6
Sawtooth generator	D, R2, R4, R5, R6
Triangular wave generator	R2, R3, R4
Pulse rate modulator (1)	D, R1, R2, R4, R5, R6
Pulse rate modulator (2)	R2, R4, R5, R6
Time delay circuit	D, R2, R5, R6
Sensitive current detector	D, R1, R2, R4, R5, R6
Temperature indicator	D, R2, R4, R5, R6
Peak voltage detector	D, R1, R2, R5, R6

Unijunction transistor takes advantage of negative resistance to spark circuit savings

The new unijunction transistor has the useful property of negative resistance. Briefly, the current rises with the voltage input as usual, but only up to a certain peak, past which the current keeps on increasing though the voltage starts going down. This principle gives the unijunction two stable states—one "off" and the other "on"—so that it can be used to take the place of two conventional transistors (minus much other circuitry) in many switching and oscillator applications. A few of these applications making use of the unijunction's high peak current capabilities combined with high temperature rating and stability are shown above.

To put the unijunction to work for you, you'll want all the specs, plus application data with sample circuits. Please write for information. As you'll see, the unijunction is actually a new type of semiconductor, the first since the conventional transistor itself to reach commercial success.

G-E High-voltage Silicon Triodes

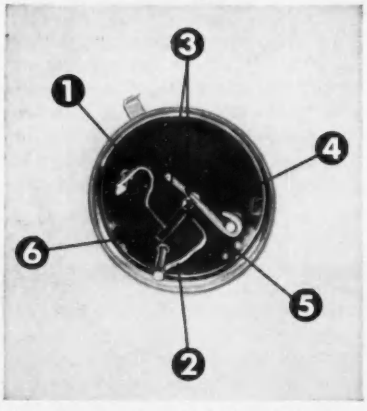


Photo shows top view of G-E silicon high-voltage transistor, with cap removed. 1. Gold emitter ribbon. 2. Aluminum base-lead ribbon. 3. Gold-silicon alloy. 4. Collector tab. 5. Base region. 6. NPN diffused meltback silicon bar. Cantilever design for shock resistance. Silicon bar is alloyed firmly to tab; ribbons are flexible to minimize constraints.

General Electric can now supply your needs for popular, industry-accepted high-voltage silicon transistors—types 2N332, 2N333 and 2N335. Every unit is aged at 200°C for more than 500 hours, and takes a drop test considered more rugged than the standard military 500 G shock test. That's why you can depend on ratings and performance characteristics shown. Rated at 45 volts (collector to base), these transistors are designed for amplifier use, both audio and RF, and general purpose switching. Among its many features are low output capacity, high cutoff frequency and low leakage. Full specs are available from your Semiconductor Sales representative or from the factory.

SPECIFICATIONS, Types 2N332, 2N333, 2N335

Absolute maximum ratings

Storage temperature	200°C
Operating temperature	—55°C to 175°C
Collector to base voltage	45 volts
Emitter to base voltage	1 volt
Collector current	25 ma
Power	
Collector dissipation (25°C)	150 mw
Collector dissipation (100°C)	100 mw
Collector dissipation (150°C)	50 mw

A section of the test area in G.E.'s Buffalo transistor plant. In the foreground is a humidity control box in which transistors are inspected prior to encapsulation.

Transistor Reliability

enhanced by spotless factory, stringent controls

The production section of G.E.'s Buffalo semiconductor plant resembles a medical research laboratory. Production workers are dressed in white; white walls and ceilings predominate. The entire plant is air conditioned and slightly pressurized so any dust will flow out instead of in when doors are opened. Water is super-purified and tested electronically, for chemical testing is not accurate enough. Alcohol used to dry transistors has to be so pure that a single drop of water in a barrel of it would ruin it.

These are just three of the manufacturing techniques that have their pay-off in reliability. They are supported by special quality control techniques using over $500,000 worth of test equipment, to help assure G-E transistors do not fail or permanently change parameters.

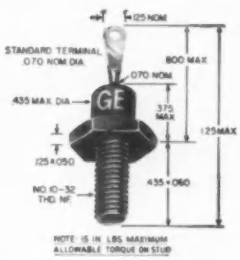
Military specifications call for dozens of rugged tests. But commercial and industrial transistors undergo most of them also, plus a few of their own. Here are some examples: Shock test: a transistor is mounted on a heavy metal block and dropped as much as 4 feet to a metal base. 20,000 G centrifuge test: transistors are spun about 36,000 rpm in various positions, then checked both mechanically and electrically. 15 minute temperature cycling test: transistors are frozen at −65°C and then immediately placed in an oven set at maximum temperature (up to 250°C). Vibration test: transistors are rattled at 40 to 100 cps for 96 hours. Salt spray test: corrosion and hermetic sealing properties are tested for periods ranging up to 12 days.

G-E Silicon Stud-mounted Rectifiers

If you're looking for greater current at higher temperatures, with no sacrifice of chassis space . . . this is just one of several advantages offered in G-E silicon low-current stud-mounted rectifiers. Other features include: • Ratings up to 170°C ambient • Low forward drop • Forward current up to 1.5 Amperes • Low leakage at high temperatures • Operating reliability assured under all conditions • May be mounted directly to heat sink using a tapped hole or a nut and lockwasher, or electrically insulated with mounting kit which is supplied with each unit.

RATINGS AND SPECIFICATIONS

	1N1115	1N1116	1N1117	1N1118	
60 cps, resistive or inductive					
Peak inverse voltage	100	200	300	400	v
RMS voltage	70	140	210	280	v
Cont. Reverse DC V	100	200	300	400	v
DC Output C (150°C Case Temp.)	600	600	600	600	ma
DC Output C (85°C Case Temp.)	1.5	1.5	1.5	1.5	amps
Full load forward voltage drop (Full-cycle ave at 150°C)	.65	.65	.65	.65	v
Leakage current (Full-cycle ave at 150°C)	0.4	0.3	0.3	0.3	ma
Max. operating freq.	100	100	100	100	kc
Ambient operating temp.	170	170	170	170	°C max.
	−65	−65	−65	−65	°C min.
Storage temp.	175	175	175	175	°C max.
	−65	−65	−65	−65	°C min.



Need a few semiconductors in a hurry?

Check your local G-E distributor

For fast delivery of transistors and rectifiers, see your local G-E distributor first. Just check and see, for yourself, if his service facilities and prices don't work out to your great advantage.

Florida engineers, for example, can call on Thurow Distributors. Thurow recently put in the most complete line of semiconductors available (G.E. of course) to better serve the greatly expanding electronic and aircraft industries throughout Florida. Shown at left are Thurow and General Electric executives looking at part of their initial shipment of G-E semiconductors.

Quick-reference transistor manual—This famous pocket-size reference is now in its enlarged second edition. Gives you all the facts—basic semiconductor theory, parameter symbols, specifications of G-E transistor types, circuit diagrams, applications, registered types of all manufacturers, and other data frequently needed. 112 pages. Available at your local G-E Tube distributor, or enclose 50 cents (no stamps, please).

YOUR G-E SEMICONDUCTOR SALES REPRESENTATIVE will be glad to give you further information and specifications on General Electric transistors and rectifiers. Manual, bulletins, and other data can also be obtained by writing Section S16158, Semiconductor Products Dept., General Electric Company, Electronics Park, Syracuse, New York.

GENERAL ELECTRIC

NEW PRODUCTS

LISTING IN GROUPS

Designs of the Month
Research & Development
Measurement & Data Transmission
Information Display Instruments
Control Devices
Power Supplies
Final Control Elements
Component Parts
Accessories & Materials

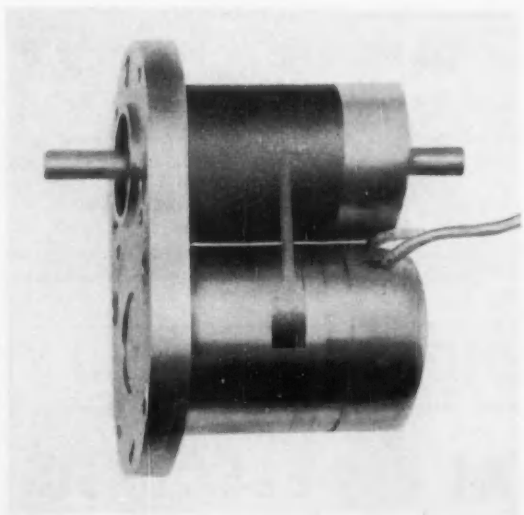
NEW ANALOG COMPUTER speeds patching.

The compact 231-R analog computer, photo at left, features a modular grouping of components that permits an operator to set up a problem on the patchboard four times faster than he could before. A prepatch panel with 3,450 holes facilitates use of bottle plugs and shorter patch cords. Complete shielding from patch cord to oven covers all possible high-impedance points.

The patchboard itself can terminate 100 operational amplifiers and associated nonlinear equipment, and has complete automatic readout. It provides for individual operational control of all integrators. Included are 30 combination summing-integrating amplifiers, 45 summing amplifiers, 25 inverters, 200 trunks, 150 coefficient pots, 20 ten-segment DFG's, 10 electronic multipliers, 10 five-channel servomultipliers, five servo resolvers, five function-of-two-variables generators, three eight-channel recorders for X-Y plotters, 10 comparators, 20 function switches, 15 limiters, 20 passive elements, and 225 jacks on the patch panel for miscellaneous expansion.

A high-speed digital voltmeter on the control panel indicates both the voltage reading and address of the component being measured. An automatic, digital input-output system permits complete control of the computer from previously prepared punched paper tape.—Electronic Associates, Inc., Long Branch, N. J.

Circle No. 1 on reply card



CLUTCH PACK has predetermined delays.

The A-100-CP Clutch Pack shown here is a one-package combination of a mechanical pulse amplifier, indexing clutch, and electrical transducer. Time for both the mechanical and electrical delays is predetermined; the design engineer need only compute the required shaft speed. Factory adjusted, the entire package is immediately operable. Despite high shaft speed and a minimum 10-lb-in. torque, the unit's combined mechanical and electrical delay time is just 0.0045 sec.

The pack consists of indexing clutch, power pack, servo bracket with mounting hardware, and a nylon link. Models are available for different voltage levels for both aircraft and industrial applications. The only mounting required is the mechanical input and the load. Applications include automatic control systems, electronic computers, data-processing equipment, and automatic machines.

The designer is offered a choice of index rate and clockwise or counterclockwise rotation.—Digitronics Corp., Albertson, Long Island, N. Y.

Circle No. 2 on reply card

FASTEST PRINTER needs no special paper.

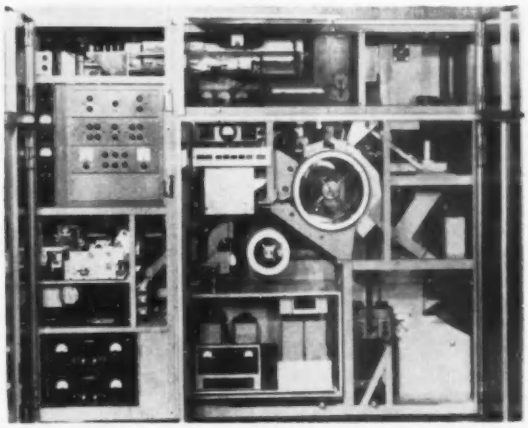
The Model 5000 high-speed electronic printer, recently introduced, represents the fastest commercially available device for high-speed printing of computer data. Featuring an output of 4,680 lines or approximately 85,000 to 100,000 words per min, the unit is a result of the combination of Stromberg-Carlson's Charactron shaped-beam readout tube and The Haloid Co.'s Xerox Copyflo printer. A variety of systems are available, depending on the application requirement. Choice of inputs permits either on-line printing, with the unit taking the computer output directly, or off-line printing from magnetic tapes. Editing devices may be used in either case. Solid-state electronic circuitry and a minimum of moving parts make for high reliability and accuracy.

In the printing operation, the face of the Charactron shaped-beam tube, acting as a projector, sensitizes the surface of a selenium drum. The latent images thus produced are developed with a dry powder electrostatically and then printed on continuous rolls of paper. If desired, an electronically controlled cutter may be added to produce sheets of any given length. Because the Xerox printer can be used with any kind of paper, the process is relatively inexpensive.

Both commercial and engineering data can be processed by this system. The off-line method will probably lend itself more readily to commercial applications, the on-line method to engineering and scientific applications.

The photos at the right show the compact internal construction of the unit and its neat external appearance. The 7-in. Charactron tube is located at the top center of the unit, with a split prism directing its output down on the xerographic drum.—Stromberg-Carlson Co., San Diego, Calif.

Circle No. 3 on reply card



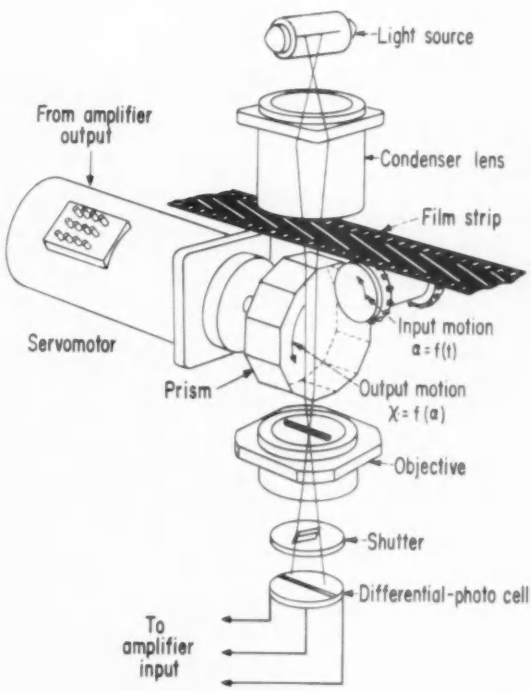
FUNCTION GENERATOR uses optics.

A new function generator, developed in Switzerland, features rugged construction and an unusual electron-optical memory. Designed as an independent unit, it lends itself readily to multiple-unit installations.

The simplified sketch at the right illustrates its operating principles. If the input shaft rotates according to the time function $\alpha = f(t)$, then the output shaft rotates according to function $x = f(\alpha)$, which is determined by the data carrier. The data carrier is a normal 35-mm film. Its direction of feed corresponds to the input signal, while its width corresponds to the output signal x. A special polydromal optical recording on the film assures high accuracy in spite of the narrow film width. The desired function is split up into equal horizontal segments and projected onto the film.

The main element of the instrument is a polydromal glass prism which refracts light rays passing through the film strip. As shown, these rays pass from the film through an objective and shutter to a differential photocell. When the rays strike the photocell symmetrically, both halves are illuminated equally and there is no output voltage to the servomotor. When the film moves according to the input signal α, the light rays are deflected according to the optical record on the film, producing an unsymmetrical illumination of the photocell. This causes an output voltage that drives the servomotor to reposition the prism until a new balance is reached. Rotation of the prism shaft is therefore a definite function of the film recording. The prism serves the purpose of putting together the projected parts of the function.—Contraves AG, Zurich, Switzerland.

Circle No. 4 on reply card



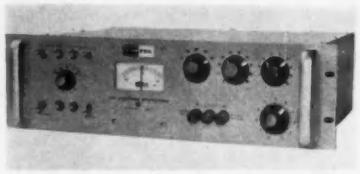
NEW PRODUCTS

RESEARCH, TEST, & DEVELOPMENT

QUICK CHECK

The Model 123 Core Tester provides a display of coercive force, saturation flux density, B_r:B_m ratio, and differential permeability of a given core, and the shape of the hysteresis loop. An optional display made on a cathode-ray oscilloscope permits a quick evaluation of the basic core characteristics in relation to a specific circuit application. The new tester uses a single-wire test probe that permits manual testing rates up to 400 cores per hour.—Mack Electronics Div. of Mack Trucks, Inc., Boston, Mass.

Circle No. 5 on reply card



STANDARD-CELL ACCURACY

The Model 301R is a compact, adjustable dc voltage standard and null voltmeter designed for mounting in standard 19-in. racks. Direct reading calibrated dials provide instant voltage selection with standard-cell accuracy. A unique chopper-stabilized circuit constantly compares the output with an internal standard cell. Power supply output voltage is 1 to 501 volts. It has four decaded null meter ranges of from 50 volts to 50 millivolts full scale. The meter can also be used to read input voltage or the output voltage of the supply. The 301R features line and load regulation within 0.002 percent, and less than 100 microvolts ripple.–KIN TEL, San Diego, Calif.

Circle No. 6 on reply card

BATTERY OPERATED

Called the Model 15A AC Electronic Voltmeter, this portable, multirange unit measures voltages from 1 mv to 300 volts full scale, within the frequency range of 30 cycles to 300 kilocycles. Highly sensitive and accurate, it provides laboratory precision under adverse conditions. Small size and light weight are the result of transistor circuitry and printed wiring. A self-contained battery power supply eliminates the disturbances caused by power-line fluctuations. Though primarily intended for the test and maintenance of telecommunications equipment having 600-ohm balanced circuits, it can also be used with unbalanced circuits.–Consolidated Electrodynamics Corp., Pasadena, Calif.

Circle No. 7 on reply card

INDICATES DEVIATION

The resistance deviation bridge shown above indicates the percentage deviation of a sample resistor from the standard resistor of the same nominal value, and can be used as a precision resistance bridge for general null balance measurements. Specific applications include separating resistors into tolerance classifications, selecting or matching resistors, and establishing conformity to specification. The unit can also be made to control automatic sorting or inspecting, and to activate various rejection mechanisms. High accuracy over a resistance range of from 1 ohm to 10 megohms is the result of a chopper-stabilized feedback amplifier and a Wheatstone bridge. Accuracy as a limit bridge is better than 0.15 percent.–Millitest Co., Hempstead, N. Y.

Circle No. 8 on reply card

ALLIED'S MHJ RELAY
Built for Shock and Vibration

10-55 cps at 0.125 inch double-amplitude • 55-2000 cps at 20g

Here are the facts:

Contact Ratings:
Low level up to 5 amperes at 29 volts d-c or 2 amperes at 115 volts a-c non-inductive or 1 ampere inductive

Contact Arrangement:
MHJ-12D: 4 PDT
MHJ-18D: 6 PDT

Temperature:
Minus 65°C to plus 125°C

Vibration:
10-55 cps at 0.125 inch double-amplitude
55-2000 cps at 20g

Operating Shock: 100g

Weight:
MHJ-12D: 3.0 ounces
MHJ-18D: 4.2 ounces

Insulation:
1000 megohms minimum

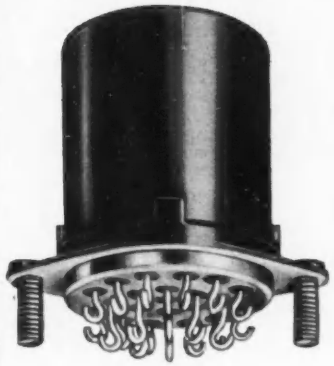
Dielectric Stress:
1000 volts rms at sea level;
500 volts rms at 70,000 feet

Initial Contact Resistance:
.03 ohms maximum at .01 to 2 amps

Operate Time:
10 milliseconds or less at rated voltage at 25°C

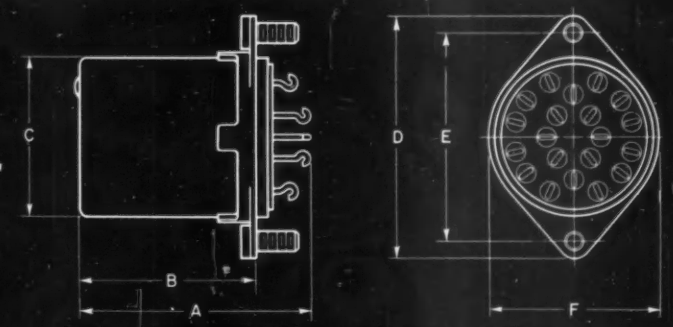
Release Time:
5 milliseconds or less at rated voltage at 25°C

Now with 5 amp Rating and Stabilized Construction*



TYPE MHJ
ACTUAL SIZE

* Includes materials and processing necessary to minimize contact resistance variations and dielectric deterioration during life due to contact contamination, mechanical wear and shift of adjustments with temperature.



MOUNTING #6-32 NC-2A THD. (2) STUDS

	A	B	C	D	E	F
MHJ-12D (4 Pole)	1¾ max.	1 5/16	1 3/64	1 21/32	1.406	1⅛
MHJ-18D (6 Pole)	1¾ max.	1 5/16	1 3/16	1 13/16	1.562	1 5/16

ALLIED CONTROL

ALLIED CONTROL COMPANY, INC., 2 EAST END AVENUE, NEW YORK 21, N. Y.

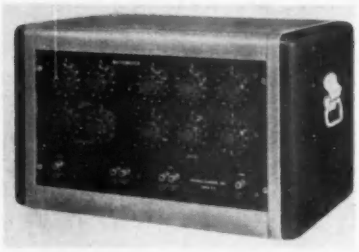
AL 10

NEW PRODUCT

MOBILE RECORDER

This mobile two-channel oscillographic recorder simultaneously depicts and records such phenomena as voltage, current, pressure, vibration, temperature, strain, acceleration, or force. Built for rough treatment, the unit will record, for example, strains as low as 10 microin. per in., and voltages as low as 1 microvolt. The 100-lb unit contains a two-channel direct-writing recorder with a choice of standard amplifiers.—Edin Co., Worcester, Mass.

Circle No. 9 on reply card



FOR VOLTAGE RATIOS

Boasting an accuracy within 5 parts per million at unity ratio, this new ac ratiometer is particularly well-suited for testing precision transformers, resistors, capacitors, and inductors. Operational at 60 or 400 cps, the instrument provides an overall frequency range of from 40 to 2,000 cps. Plug-in units are available on order to cover any specified frequency. Quadrature voltage injection and filtering eliminates effects of both quadrature and harmonics. A transistorized amplifier provides enough gain to feed the null signal directly to an oscilloscope.—Tranformers, Inc., Vestal, N. Y.

Circle No. 10 on reply card

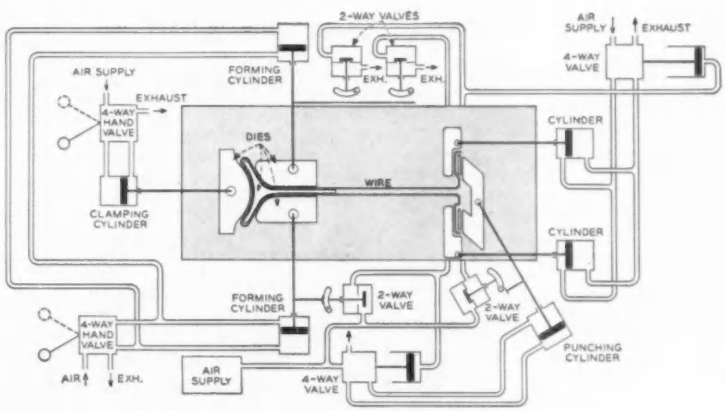
***Progress** in plan-it-yourself air systems:*

How one plant cuts forming costs 75% with Schrader Air Products adapted to jig

Outdoor grill legs formed. Operator places wire between dies. Note Schrader products. Schematic below gives Schrader "Air layout" at end of cycle with wire formed.

Before this Schrader-powered forming jig was installed, an Ohio plant used heavy punch press equipment and costly welding procedures. Now man-hours and materials have been released for other work, and a single operator produces the finished part in seconds, effortlessly. Cutting the cost of the finished product by ¾!!

Every day Schrader Air Products are being integrated into the most diverse types of manufacturing operations. Versatile, safe, accurate air often makes the difference between profit and loss. And air acts faster than you think! Look into the opportunities in your own plant for modernizing with air. Schrader engineering facilities are available upon request to assist you in planning. Why not mail the coupon today?



Schrader
a division of **SCOVILL**

QUALITY AIR CONTROL PRODUCTS

A. SCHRADER'S SON • Division of Scovill
471 Vanderbilt Avenue, Brooklyn 38, N. Y.

If they can save money with air in Ohio—maybe we can, too!

Please send latest informative booklets which show Schrader's complete line of products.

Name_____ Title_____

Company_____

Address_____

NEW PRODUCTS

WELL PROTECTED

The Model 3050-5 DC Overpotential Tester has an output range of 0 to 50 kv at 0 to 5 ma, a single-phase input of 105 to 125 volts, 50 to 60 cps, reversible polarity, and less than 2 percent ripple at full resistive load. A few of its protective features: an automatic output-voltage shorting mechanism, an over-voltage relay adjustable from 10 to 105 percent of rated output, an overcurrent relay preset at 120 percent of rated output, and gaseous discharge devices for protecting relays and meters.—Beta Electric Div., Sorensen & Co., New York, N. Y.

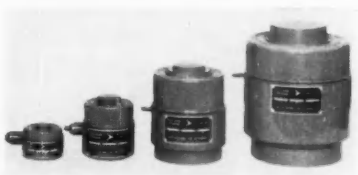
Circle No. 11 on reply card

MEASUREMENT & DATA TRANSMISSION

CHECKS ITSELF

A new self-calibrating accelerometer, the Model ADT-905, has a built-in system that can be used to check the operation of the unit while in use, or to calibrate the accelerometer either statically or dynamically. The self-calibrating system incorporates a force-generating device which applies a force to the seismic system in proportion to the electrical excitation. Balanced electrical and mechanical construction assures temperature stability over the range of minus 65 to plus 250 deg F. The unit operates at a low natural frequency of about 30 cps, and is said to maintain stable frequency response characteristics as a result of magnetic damping.—Gulton Industries, Inc., Metuchen, N. J.

Circle No. 12 on reply card



RANGES TO 200,000 LB

The construction of a new series of precision strain-gage load cells for measuring forces and weights provides up to 250 percent greater output, with consequent reduction of interference from stray signals. The compression cells, in small, hermetically sealed housings, are designed in nine capaci-

transistor power supplies

NEWLY DESIGNED FOR TRANSISTOR VOLTAGES

• 3 RANGES—FINE RESOLUTION • TUBELESS
• LOW COST • CONTINUOUSLY VARIABLE

These new T-Nobatrons are the perfect solution to the problem of providing well-regulated voltages for the development and testing of transistor circuits. They provide stable DC output voltages in three ranges, with fine resolution. Excellent transient response for line and load pulses. Simple tubeless construction means greater reliability, lower cost, Also ideal for many other applications in these voltage ranges, such as relay testing and computer circuitry development.

DUAL RACK INSTALLATION

ELECTRICAL CHARACTERISTICS

Model	T50-1.5	T60-5	T120-2.5
AC Input (60 ~ , 1φ)	95-130	95-130	95-130
DC Output Voltage	0-10	0-10	0-25
(three ranges)	0-25	0-25	0-50
	0-50	0-60	0-120
Output Current (amps.)	0-1.5	0-5	0-2.5
Regulation, line: 105-125 V	±1%	±0.5%	±0.5%
For wider input	±2%	±1.0%	±1%
Internal Resistance, typical (ohms)			
low-voltage range	1.2	0.35	1.3
middle range	2.1	0.55	2.0
high range	4.5	1.0	4.0
Ripple (mv)	50 max.	50 max.	50 max.
Time Constant (line)	0.08 sec.	0.08 sec.	0.08 sec.
(load)	0.15 sec.	0.15 sec.	0.15 sec.

MODEL T50-1.5

SORENSEN & COMPANY, INC. Sorensen® **SO. NORWALK • CONN.**

In Europe, contact Sorensen-Ardag, Eichstrasse 29, Zurich, Switzerland, for all products including 50 cycle, 220 volt equipment

NEW PRODUCTS

ties ranging from 500 to 200,000 lb. A special cell cable features zero moisture absorption and a stainless-steel jacket. – Cox & Stevens Electronic Scales Div. of Revere Corp. of America, Wallingford, Conn.

Circle No. 13 on reply card

CHECKS DENSITY

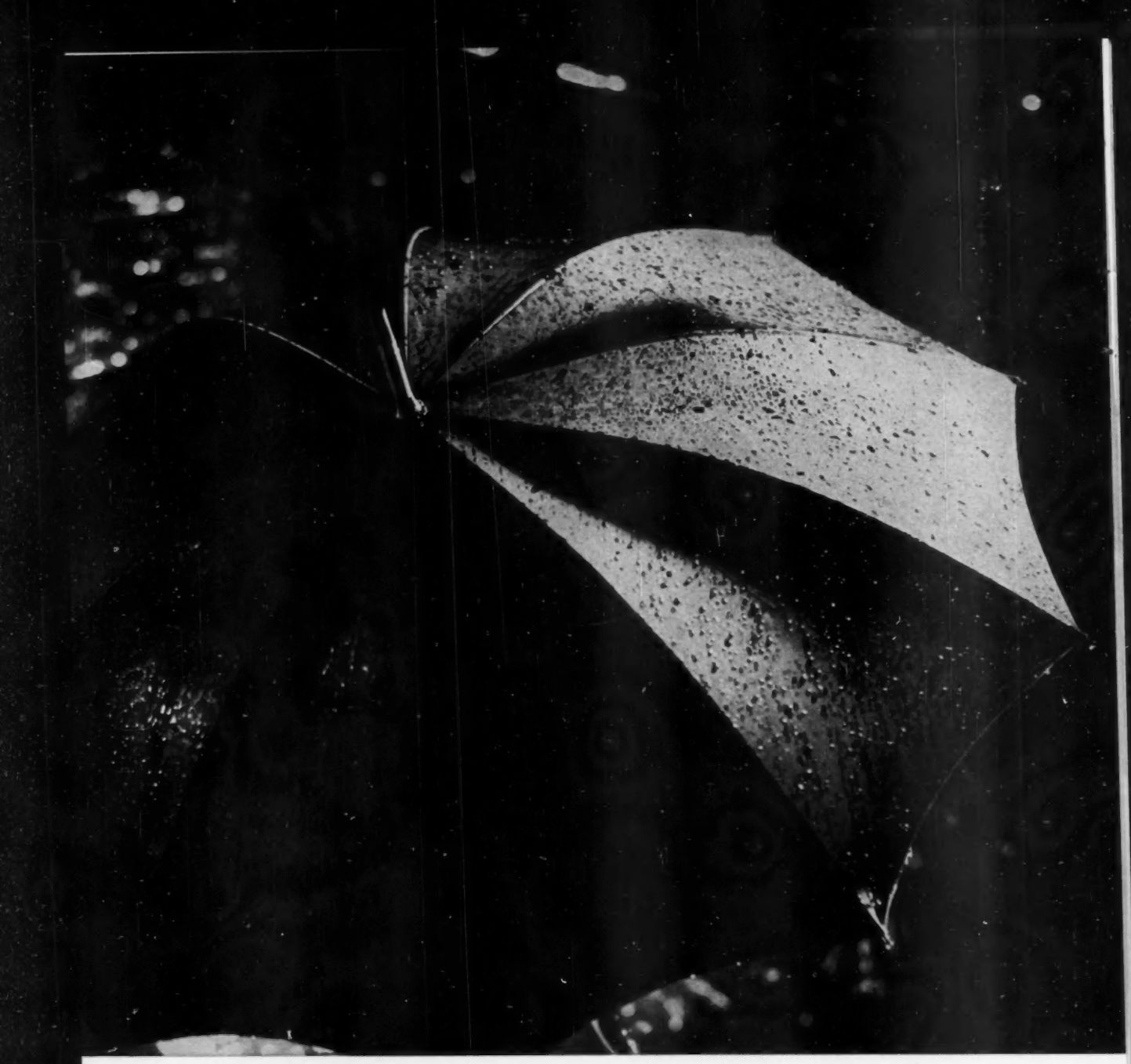
A new density measuring system, Model P-625, permits measurement of liquid density during transit, in storage, or throughout the complete cycle of a reaction. Automatic and continuous, the instrument is suited for either control or monitoring operations. It consists of a probe and a power supply and may be used in conjunction with a standard recorder or indicator. Accurate to within plus or minus 0.001 gram, it is unaffected by pressures from 0 to 125 psi.–General Communication Co., Boston, Mass.

Circle No. 14 on reply card

RUGGED PICKUP

Essentially a moving-coil device, the Dynavolt Vibration Pickup converts motion into a voltage. Resonant frequencies of from 7 to 80 cps permit use of the device as a displacement, velocity, or acceleration transducer. Outputs as high as 1 volt per in. per sec may be had under critically dampened operation. Coil resistances from 125 to 1,000 ohms may be specified. A unique spring suspension system provides extremely rugged construction, while limit stops eliminate stress concentration points. Case sizes vary from 2¼ in. in diam by 3 in. high down to 1⅝ in. in diam by 1¾ in. high.–Mandrel Industrial Instruments, Houston, Tex.

Circle No. 15 on reply card



GPE — technological bumbershoot

Covering the advanced needs of industry and defense is today's biggest technological job.

GPE has brought together, under one umbrella, broad physical resources plus a remarkably creative group of scientists, engineers and technicians. Its co-ordinated skills, knowledge, experience and producing facilities cover more than a dozen industries.

Each company in General Precision Equipment Corporation works close to the frontiers of science in its specific fields. Working together, they have rolled up an impressive record of achievement in new and often uncharted technological areas.

If your needs are in controls, systems engineering or automation, you'll find some eye-opening answers in this highly integrated research, design, engineering and manufacturing group.

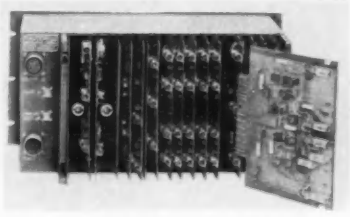
GENERAL PRECISION EQUIPMENT CORPORATION

NEW PRODUCTS

FOR 40 TO 2,000 CPS

Designed to standards of laboratory accuracy, this new vibration pickup fills all the requirements of operational use. Called the Type 4-120 Vibration Pickup, it was developed for ground and in-flight monitoring of jet engines, but can be used in all high-frequency, low-amplitude vibration studies under extremes of temperature. Maximum acceleration without damage is 50 g's. Insensitive to transverse vibration, the unit will produce a signal directly proportional to the velocity as low as the recording equipment will measure. Among important design features is the use of two magnets, one to control sensitivity, the other to control damping. This permits adjustment of the critical damping for temperatures up to 400 deg. F.—Consolidated Electrodynamics Corp., Pasadena, Calif.

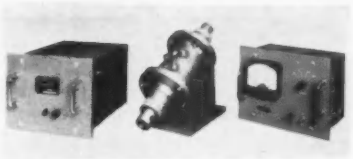
Circle No. 16 on reply card



PRECISION CONVERTER

The new all-electronic Type 525 Encoder provides for precise and dependable conversion of analog input data into digital output voltages. Particular emphasis is placed on accuracy and resolution. The device permits the use of versatile, noise-free digital transmission and computing techniques, to attain a degree of accuracy heretofore impossible.—Avion Div. of ACF Industries, Inc., Paramus, N. J.

Circle No. 17 on reply card



NEEDS NO ELECTRODES

The three units above constitute a patented "electrodeless" system for measuring electrolytic conductivity. Not meant to replace conventional techniques, the new system is recommended only under certain conditions, as in the presence of fibers which tend to clog standard conductivity cells, abrasive slurries, hot highly conductive solutions, or extremely corrosive solutions. The cell itself may be mounted either in the main stream or in a sampling line. It features two externally mounted toroids. A transmitting unit feeds the input toroid a stable voltage in the high audio frequency range. Since the flux linking the two toroids passes through the liquid, the strength of the output toroid voltage is a function of the conductivity of the solution.—Industrial Instruments Inc., Cedar Grove, N. J.

Circle No. 18 on reply card

FOR MISSILE TESTING

Minimum response to vibration makes this lightweight potentiometer pressure pickup well-suited for in-flight missile applications. Known as the Type 4-380, it measures absolute and differential pressures of noncorrosive fluids up to 100 psi. An inherently high-level dc output eliminates the need for amplifying equipment. Measured pressure goes directly to a force-summing pressure capsule and remains outside the potentiometer system. The unit weighs about 8 oz, has a 2¼-in. mounting base, and will operate in a temperature range of minus 65 to 200 deg F.—Consolidated Electrodynamics Corp., Pasadena, Calif.

Circle No. 19 on reply card

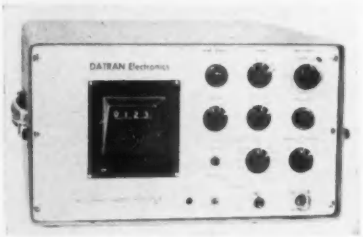
NEW PRODUCTS

ACCURATE RESOLVER

Developed at Bell Labs under an Air Force contract, a new electromagnetic angle transducer provides a resolution of better than plus or minus 3 sec of arc. Applications include visual and automatic angle reading in machine shop and military equipment. (It has already been used in an angle encoder that converts shaft position to a numerical representation acceptable to a digital computer. Here the error of the complete encoder is less than 10 sec of arc.) The vernier resolver is actually a reluctance-type variable coupling transformer. In the present design, two output voltages vary in amplitude as the sine and cosine of 27 times the angle through which the shaft is turned.—Clifton Precision Products Co., Clifton Heights, Pa.

Circle No. 20 on reply card

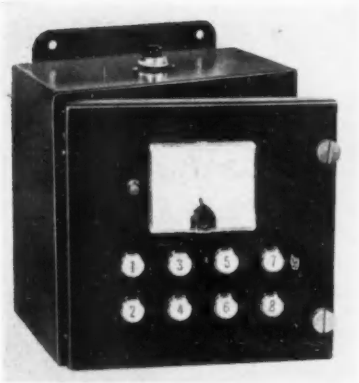
INFORMATION DISPLAY INSTRUMENTS



TRUE UNIT READOUT

Pictured is a brand-new indicator that accepts inputs from resistance-type transducers such as strain gages, load cells, resistance bulbs, etc., via a null-balance servo, and converts these analog signals to digital readout in true units of measurement. For example, if the instrument is used for load cell measurement, the readout is in actual pounds. For strain gages readout is in microinches per inch. Panel controls permit adjustment to accommodate full- or half-bridge transducers with 1, 2 or 4 active legs, and for the proper polarity. Other controls regulate amplifier gain and balance, and permit transducer calibration with built-in precision resistors of various ranges. Visual or automatic digital readout is available.—Datran Electronics, Manhattan Beach, Calif.

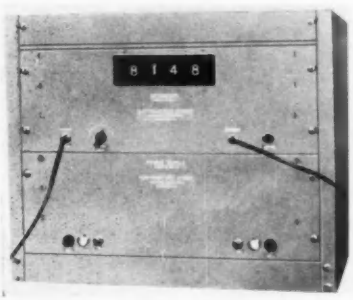
Circle No. 21 on reply card



VERSATILE SCANNER

Shown is a versatile multipoint temperature scanner that provides over- or under-temperature protection for several control points of a system. Four to 56 thermocouples may be connected to a special stepping switch that samples the output of each. When any temperature exceeds preset limits, an alarm sounds, a light corresponding to the offending thermocouple remains lit, and the scanner stops at that particular point. Scanning rates may be as high as 120 points per min or, for more practical purposes, one to 12 points per min.—Tipptronic, Inc., Chagrin Falls, O.

Circle No. 22 on reply card



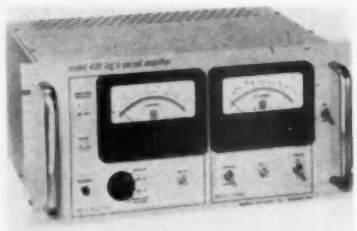
NO LOST TIME

The O-P-T-I-METER (Occurrences Per Time Interval Meter) is a four-decade instrument that counts, samples, stores, and provides a working output without stopping the count or losing time between samples. Information is transferred from the counter to a storage output in less than 50 microsec, or while the counter resets automatically to accept the next sample. The storage output continuously displays the last count sampled. Provisions have been made for relays, numerical indicators, and printers. The rack-mounted unit has a maximum counting rate of 100 kc-volt, with a 5-volt input signal. A 40-volt, 2-mi-

NEW PRODUCTS

crosec transfer pulse is required for sampling.–Electronic Tube Div. of Burroughs Corp., Plainfield, N. J.

Circle No. 23 on reply card

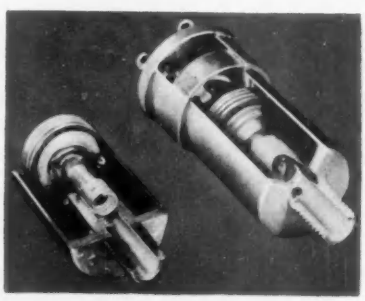


COMBINED INDICATOR

The Model 420 log n period amplifier combines a logarithmic micro-microammeter and a reactor period meter. It measures current from 10^{-13} to 10^{-4} amp and positive or negative reactor period from 3 to 30 sec. After warmup, drift of the log circuit is within 0.05 decade in 24 hours. The period meter has 5-sec recovery time from overload and adjustable response time over a 10-to-1 range. Features include large full-scale outputs to drive remote meters, 50-mv outputs for recorders, a regulated 225-volt polarizing potential for ion chambers, and simplified operating and calibration controls.–Keithley Instruments, Inc., Cleveland, Ohio.

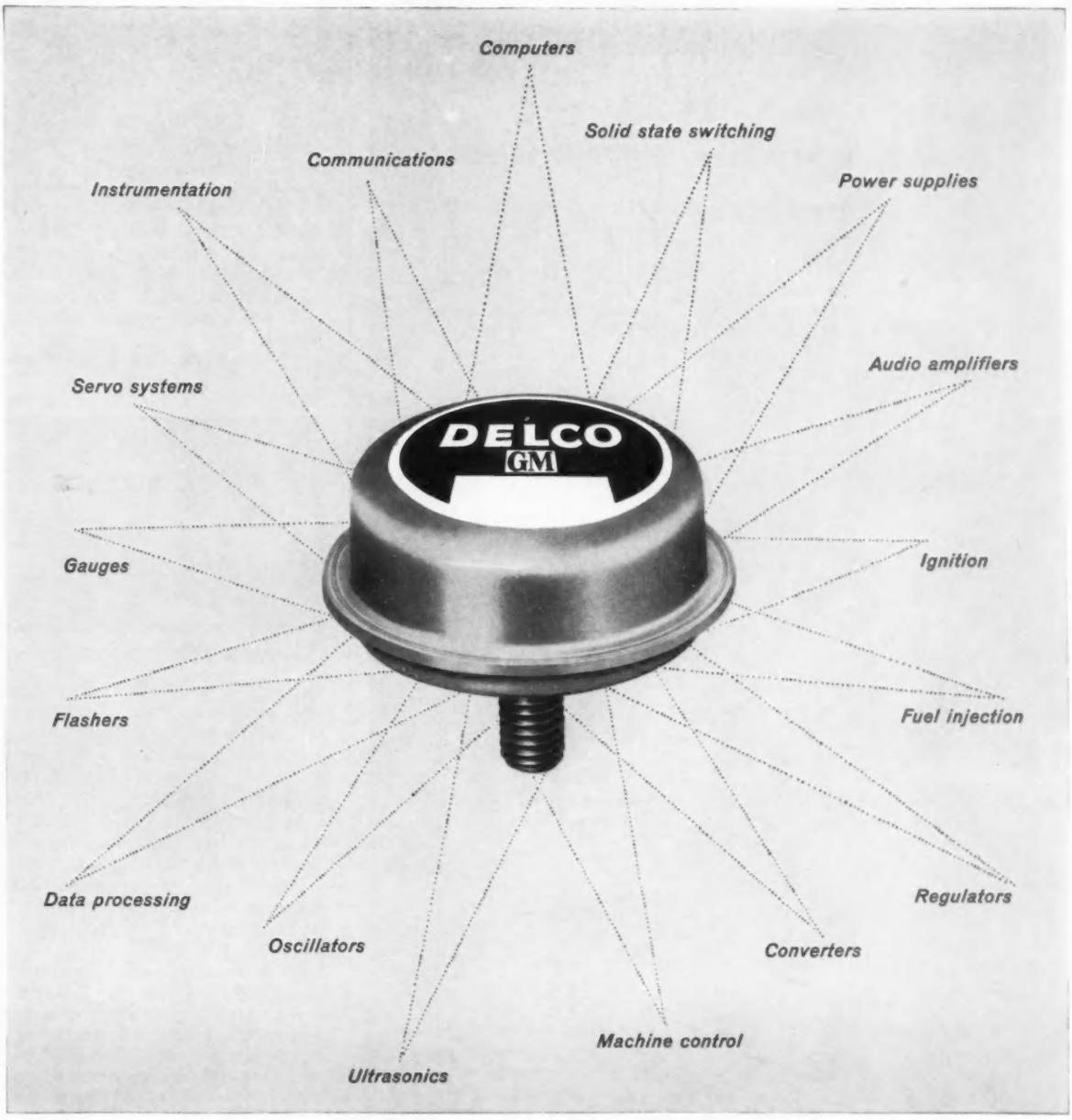
Circle No. 24 on reply card

CONTROL DEVICES



EASILY CALIBRATED

The new RS Series pressure switches, designed for operation under extremes of temperature, shock, and vibration, feature a new self-locking screw adjustment for fast, accurate pressure-range calibration. A single coil near the center of a Heli-Coil insert approximates a polygon in shape instead of a



Wherever you require high power, consider

DELCO HIGH POWER TRANSISTORS

Thousands of Delco high power germanium transistors are produced daily as engineers find new applications for them. In switching, regulation, or power supplies—in almost any circuit that requires high power—Delco transistors are adding new meaning to compactness, long life and reliability.

All Delco transistors are 13-ampere types and, as a family, they offer a collector voltage range from 40 to 100 volts. Each is characterized by uniformly low saturation resistance and high gain at high current levels. Normalizing insures their fine performance and uniformity regardless of age. Also important—all Delco transistors are in volume production and readily available at moderate cost.

For complete data contact us at Kokomo, Indiana or at one of our conveniently located offices in Newark, New Jersey or Santa Monica, California. Engineering and application assistance is yours for the asking.

DELCO RADIO DIVISION OF GENERAL MOTORS, KOKOMO, INDIANA

NEW PRODUCTS

circle. The chords of the coil thus formed grip the adjusting screw in any desired position. The adjusting screw itself is brazed to one end of a phosphor bronze bellows, thus permitting external adjustment of the gap between bellows and contact. Units will deliver an electrical response to pressures ranging from 5.5 psia open and 7.5 psia closed, to 21.5 psia open and 23.5 psia closed.–Newark Controls, Newark, N. J.

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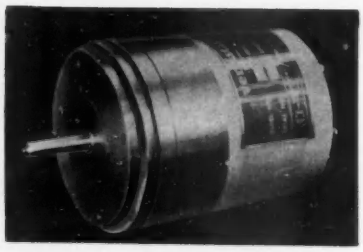


COMPACT AND LINEAR

This new type of Vernistat variable ratio computing transformer features an open-circuit linearity of plus or minus 0.1 percent and a substantial power output, sufficient in many cases to eliminate power amplifiers. Model 20-C is suited for application in analog computers where the product of a voltage and a shaft angle is needed, in the control of two-phase servomotors, and in the supply of power to torque motors. At an input of 115 volts, 400 cps, output voltage range is plus or minus 80 volts. Under maximum load conditions the quadrature component of output is approximately 5 mv per volt of primary excitation.–Perkin-Elmer Corp., Norwalk, Conn.

Circle No. 26 on reply card

LOW POWER TIMER

A new series of precision interval timers uses the basic construction of a repeat cycle timer, but has a novel

TUNG-SOL GERMANIUM PNP TRANSISTORS

in JETEC 30 (TO-5 OUTLINE) Package

. . . the Industry-Standard Package

All desirable electrical characteristics, without difficulty over mechanical and electrical interchangeability, are available to users of germanium PNP transistors in the industry-standardized JETEC 30 (TO-5 OUTLINE) package.

The JETEC 30 package can be welded to produce a more dependable hermetic seal with complete absence of flux gases. Its cylindrical shape, plus flange and base design, has high mechanical strength and facilitates uniform and positive welding. The form factor and basing design facilitate accurate, automatic assembly with printed circuits.

Tung-Sol JETEC 30 transistors are hermetically sealed in a controlled atmosphere to insure freedom from moisture and other contamination often produced by heat-conducting substances . . . the ultimate assurance of high reliability and long operating life.

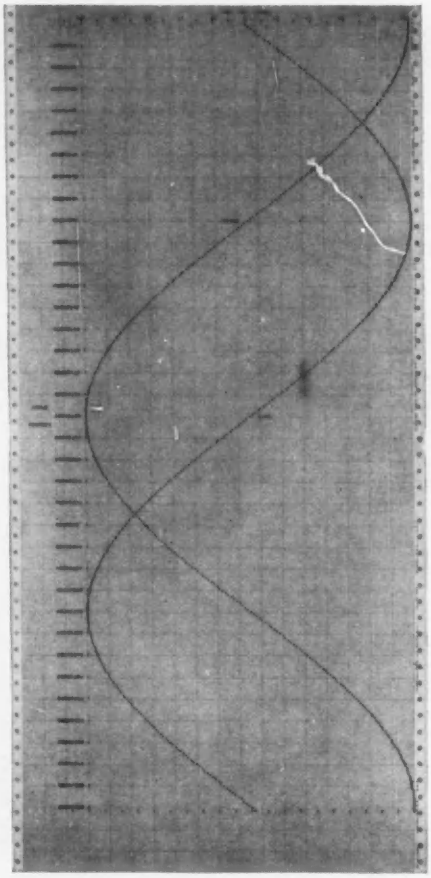
For additional information contact Semiconductor Division, Tung-Sol Electric Inc., Newark 4, N. J. or the sales office nearest you.

PRINCIPAL CHARACTERISTICS OF TUNG-SOL TRANSISTORS

2N381	200 m.w.	dissipation rating	high current	beta control
2N382	200 m.w.	dissipation rating	high current	beta control
2N383	200 m.w.	dissipation rating	high current	beta control
2N398	105v	collector voltage		
2N404	12 m.c.	frequency cut off		
2N425	4 m.c.	frequency cut off	20v	V_{ceo} rating
2N426	6 m.c.	frequency cut off	18v	V_{ceo} rating
2N427	11 m.c.	frequency cut off	15v	V_{ceo} rating
2N428	17 m.c.	frequency cut off	12v	V_{ceo} rating
2N460	200 m.w.	dissipation rating	45v	collector rating
2N461	200 m.w.	dissipation rating	45v	collector rating

SEMICONDUCTOR DIVISION TUNG-SOL ELECTRIC INC., NEWARK 4, N. J.

SALES OFFICES: ATLANTA, GA.; COLUMBUS, OHIO; CULVER CITY, CALIF.; DALLAS, TEXAS; DENVER, COLO.; DETROIT, MICH.; IRVINGTON, N. J.; MELROSE PARK, ILL.; NEWARK, N. J.; SEATTLE, WASH.

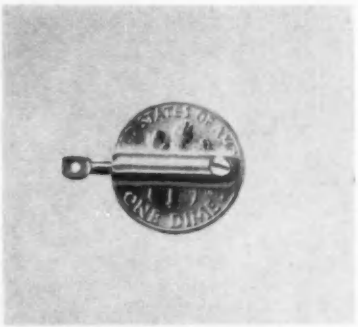


This is a greatly-reduced reproduction of sine and cosine curves demonstrating the ability of a standard tabulator to present data in graphical as well as printed form.

NEW PRODUCTS

switching system that permits high accuracy over long-range timing intervals. Available with either chronometrically governed dc motors or synchronous ac motors, these units have a range of adjustment determined by the application requirements. Overall ranges in excess of 30 to 1 can be supplied. A double dial provides maximum setting ease and accuracy, one dial showing the major setting increments and the other providing vernier adjustments. Because no standby power is required when the unit is timed out, power consumption is only a few watts.–A. W. Haydon Co., Waterbury, Conn.

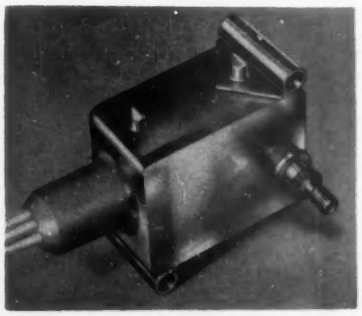
Circle No. 27 on reply card



SMALLEST THERMOSTAT?

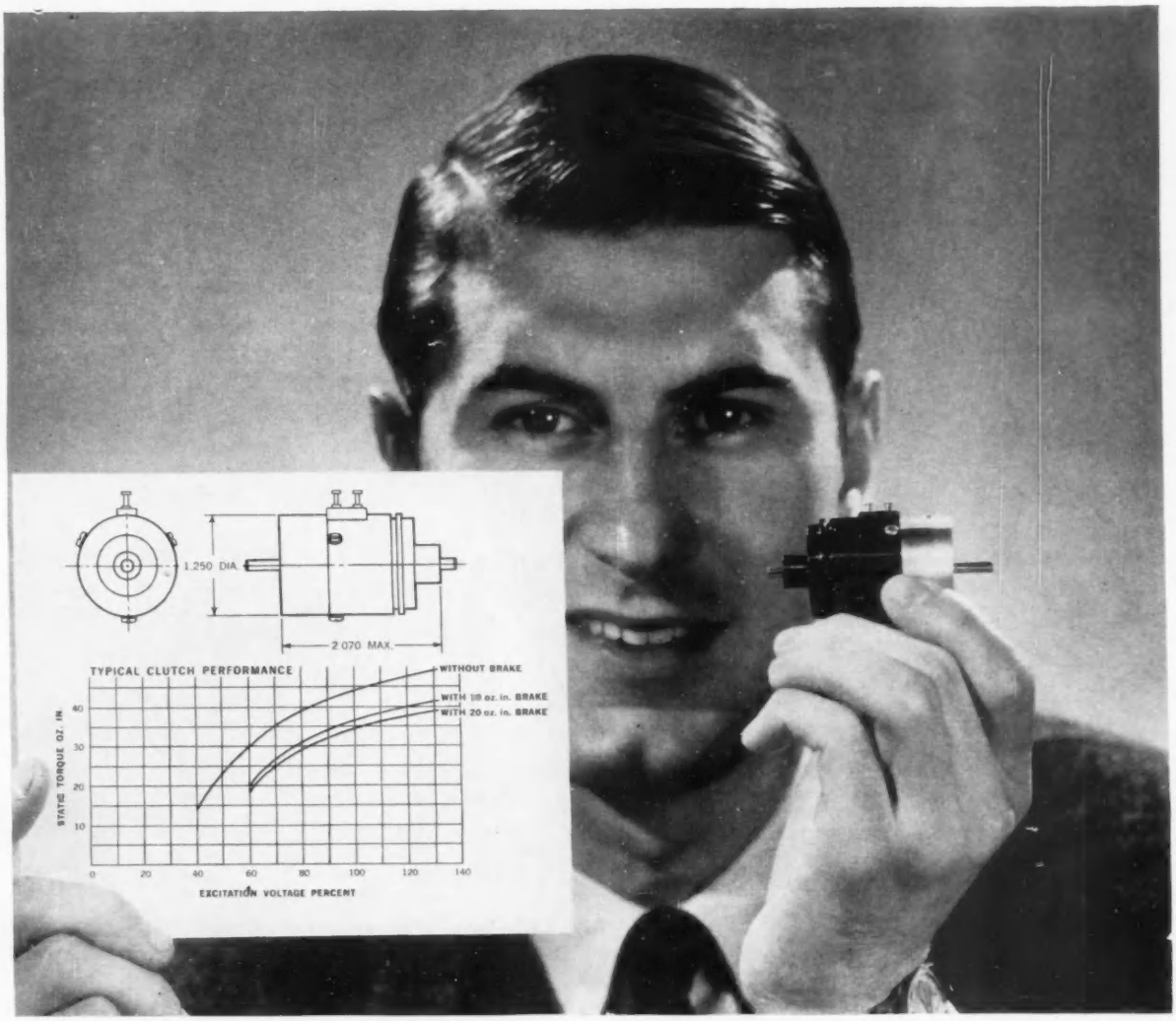
Just $\frac{7}{16}$ in. in diam by 0.690 in. long, the new Model WP Thermostat incorporates a bimetal-actuated contact and is rated at $\frac{1}{2}$ amp for 6 to 28 volts ac or dc, and 115 volts ac. Externally adjustable temperature range is from minus 65 to plus 150 deg C. Unit weighs only 0.06 lb.–Chatham Controls Corp., Chatham, N. J.

Circle No. 28 on reply card



ENVIRONMENT-FREE

An assembly of two hermetically sealed basic switches, this new rotary switch is designed for aircraft landing gear



GLOBE MINIATURE CLUTCHES & CLUTCH-BRAKES RELIABLY HANDLE LOADS FASTER THAN 1ms

We can say with confidence that Globe clutches and clutch brakes are the best that money can buy. In 4 years of production we have deliberately refined and simplified the design. Result: reliability, maximum performance and design freedom.

Epoxy potted coil is moisture and vibration proof, stable to 125° C. Precision ABEC 5 ball bearings are standard.

PARAMETERS	ENGAGEMENT TIME	RELEASE TIME
Standard Clutches	14 ms.	2 ms.*
Special Clutches	4 ms.	2 ms.*
Standard Clutch Brakes	14 ms.	14 ms.
Special Clutch Brakes	5 ms.	5 ms.
Special units with built-in loads, such as a potentiometer	4 ms.	less than 1 ms.

*when application requires

In general, we can **improve** either engagement or release time, but not both together. Options include voltage choice, input-output shaft position choice. Because standard parts for Globe units are inventoried, and clutch design a specialty, you get prototypes within weeks! Inquire from the largest miniature motor manufacturer first. Globe Industries, Inc., 1784 Stanley Avenue, Dayton 4, Ohio. Telephone BAldwin 2-3741.

GLOBE

and engine controls, missile launchers, radar, and other military and industrial applications. It will handle 10 amps resistive, 30 vdc, and 115 vac. In the model shown, the actuator shaft can continuously rotate 360 deg in either direction. Other models have limited rotation shafts or are spring-returned. Connectors and potted leads are optional, and there is a choice of actuators.—Metals & Controls Corp., Attleboro, Mass.

Circle No. 29 on reply card

POWER SUPPLIES

RUGGED PACKAGES

Two new modular-type dc power supplies are now available for applications in laboratory, test bench, or original equipment. Units are carefully engineered for chassis or subchassis use, and can be ordered for rack-mounting applications. Models RS-317 and RS-217-A are similar except for output voltage ranges. Output of the former is 225-325 vdc at 175 ma continuous duty, while that of the latter is 150-225 vdc at 175 ma. Both operate on an input of 105 to 125 vac, 60 cycles. Dimensions for both models are 7¼ in. by 5½ in. by 6½ in. high.—Trans Electronics, Inc., Canoga Park, Calif.

Circle No. 30 on reply card

SPACE SAVER

A new line of lightweight, space-saving stationary batteries is particularly suited for switch gear, alarm system, control, emergency light, and other applications requiring stand-by emergency power. Available over a capacity range of from 40 to 960 amp-hours, the new line is designed for full-float

and valuable goodwill walked away

You have encountered this situation often in the past.

But it doesn't happen very often any more . . . for a very good reason.

Today, on a multi-million dollar airplane, practically all the electrical and electronic control systems are designed on a modular or "black-box" basis. Using Cannon Connectors for quick plug-in and quick disconnect, defective control elements may be replaced in seconds . . . and the aircraft usually returns to flight before the defective units get to the shop.

Are the controls in your electrical or electronic product designed on the modular basis? How about your production line? Will a minor failure cause breakdown of the entire automated system that takes hours of down time to repair? Or are the controls of your product . . . and those in your plant . . . designed so that defective units anywhere may be disconnected and instantly replaced?

Cannon makes over 27,000 different electrical connectors. If one of these does not meet your requirements, we'll design and make the connector you need. Write today! Cannon Electric Co., 3208 Humboldt St., Los Angeles 31, Calif. Please refer to Dept. 422.

Send for explanatory material on how modular designs can save dollars.

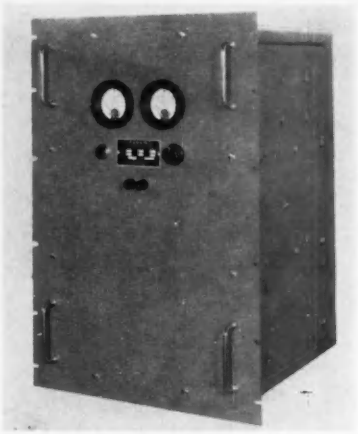
CANNON PLUGS

Where Reliability for Your Product Is Our Constant Goal

NEW PRODUCTS

service. A rugged Plastrite jar saves 30 to 40 percent floor space, permits increased battery-room capacity, and reduces storage rack requirements.—Gould-National Batteries, Inc., Trenton, N. J.

Circle No. 31 on reply card

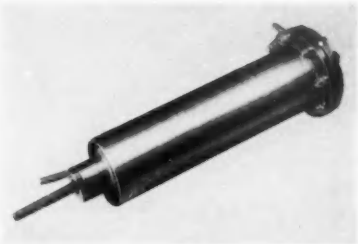


FOR MISSILE CHECKOUT

A new line of dc power supplies has been especially designed for use in missile test, checkout, and actual launching. Special design features include MIL type components such as MIL-T-27A Grade 3 magnetic components, ruggedized construction for mounting in missile vans, and a 19-in. rack panel. Voltage outputs range from 24 to 40 vds at load capacities of from 30 to 500 amps.—Perkin Engineering Corp., El Segundo, Calif.

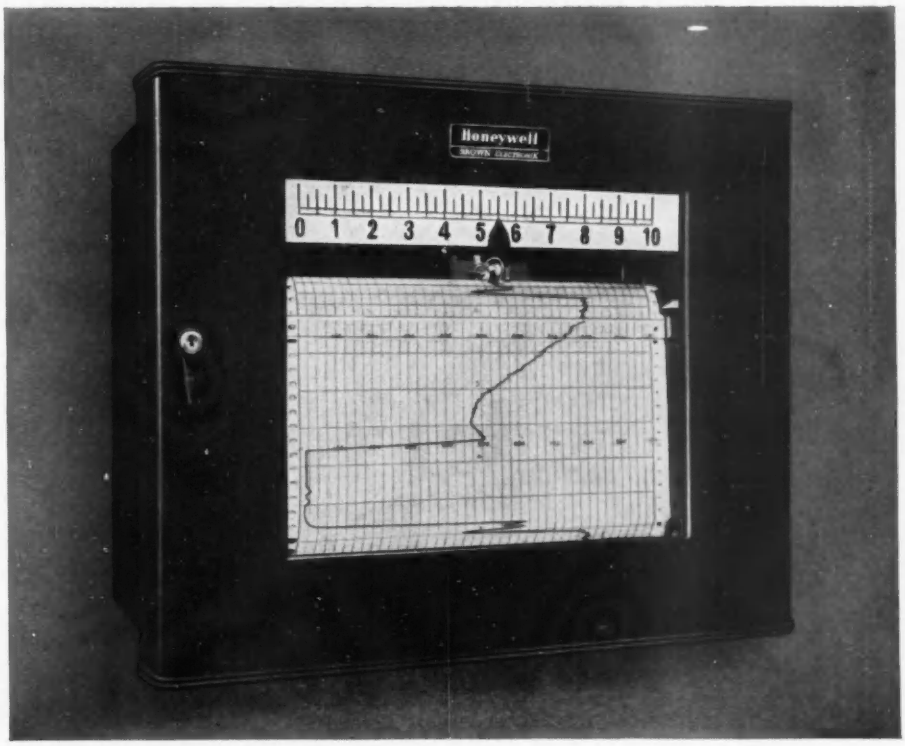
Circle No. 32 on reply card

FINAL CONTROL ELEMENTS



COMPLETELY SEALED

Designed for handling jet engine thrust reversers and other high-temperature devices, this new actuator has performed successfully at 1,200 deg



¼, ½ and 1-second recorders speed research and test projects by preserving accurate data.

Measure rapidly changing variables with *ElectroniK* fast speed recorders

Its high-speed recording makes the *ElectroniK* instrument ideal for accurately measuring split-second changes in many types of variables. Three models are available, with pens which traverse the full 11-inch width of the chart in ¼, ½ or 1 second.

ElectroniK fast speed recorders combine the accuracy and dependability of standard *ElectroniK* instruments with special pens, specially geared motors and high powered amplifiers . . . to give precise, complete records.

You'll find these recorders particularly valuable in rocket or guided missile testing, spectography and other analyses, and jet engine development. Use them to measure thrust, torque, strain, temperature, pressure, fuel and air flows, and other rapidly changing variables requiring continuous, accurate recording.

Get complete details from your nearby Honeywell field engineer. He's as near as your phone.

MINNEAPOLIS-HONEYWELL REGULATOR CO., *Industrial Division*, Wayne and Windrim Avenues, Philadelphia 44, Pa.

Honeywell

H HONEYWELL

First in Controls

NEW PRODUCTS

F using 220-psi bleed air off a jet engine. It eliminates the labyrinth or controlled-leakage-type seals, and is completely sealed at both ends. An Inconel-X spring seal is used at one end, and a wedge seal at the other.—Skinner Seal Co., Santa Ana, Calif.

Circle No. 33 on reply card

FOR AIR CONTROL

A brand new series of pilot valves has a simplified design that permits both cover and solenoid to be removed in seconds without the use of tools. Included are straightway, three-way, and four-way models. Side, base, or in-line mountings can be provided. Current requirements are 0.81-amp inrush and 0.125-amp holding at 115 volts, 60 cycles. Working pressure is 150 psi air. All models have standard ¼-in. porting.—Mechanical Air Controls, Detroit, Mich.

Circle No. 34 on reply card

COMPONENT PARTS

TEMPERATURE STABILIZED

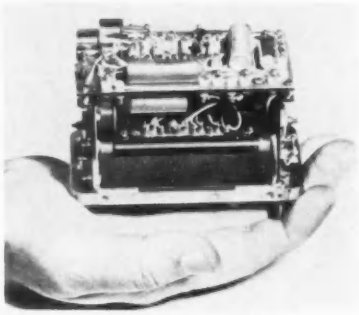
Two new 4-watt diffused-base silicon transistors are now available for medium-power transistorized circuits. Dissipation ratings of 4 watts at 25 deg C and 1 watt at 150 deg C constitute a built-in safety factor for lower power circuitry. Both are n-p-n types and feature a typical saturation resistance of 20 ohms at 25 deg C, and an operating temperature range of minus 65 to 200 deg C.—Texas Instruments, Inc., Dallas, Tex.

Circle No. 35 on reply card

WIDE APPLICATION

The A4W group of Isoformers are the first in a series of special isolation transformers that feature a secondary winding with the following properties: very low shunt capacitance to ground, very low capacitance to primary winding, high leakage resistance to both primary and ground, and high breakdown voltage to ground (greater than 2,500 volts). Units are designed to operate from an input of 117 vac, 60 cps. Output voltages from 2.5 to 150 vac at 4 watts are available. Applications include dc isolation, such as in electrometer applications, low shunt capacitance sources of filament and heater energy for high-speed circuits where the cathode has a high signal potential to ground, and noise-free sources of filament heater energy for sensitive video and instrument amplifiers.—Elcor Inc., McLean, Va.

Circle No. 36 on reply card



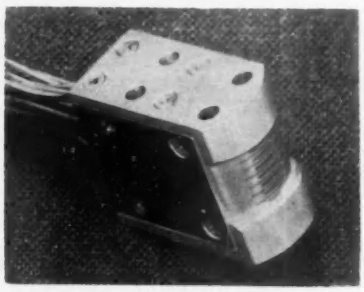
FOR ACCURATE TIMING

Featuring a new type of electronic tuning fork, this miniaturized, transistorized frequency standard permits the development of highly accurate miniature timing systems. Applications include aircraft and missile guidance systems, airborne power generators, and nuclear counting. According to the manufacturer, it would take months to accumulate an error or just 1 sec. Temperatures well above 100

NEW PRODUCTS

deg C, and other adverse environmental conditions, will not affect its accuracy. – Instrument Div. of The Hamilton Watch Co., Denver, Colo.

Circle No. 37 on reply card

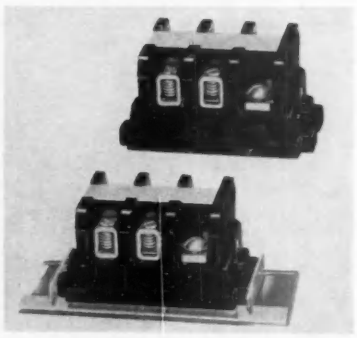


DESIGNED FOR MISSILES

This seven-channel magnetic-tape recording head can record temperatures directly from thermocouples without the use of amplifiers, using only 20 microwatts. Designed for missile applications, the unit will withstand high shock and vibration forces as well as high temperature and thermal shock. Other features include gap alignment scatter under 1/10 mil and integral tape guides.–Data Storage Devices Co., Van Nuys, Calif.

Circle No. 38 on reply card

ACCESSORIES & MATERIALS



SPEEDS ASSEMBLY

These new medium-duty, sectional terminal blocks require no fastening hardware between sections, thus simplifying on-the-job assembly to any number of circuits. Tubular contacts for stripped wire or for combinations

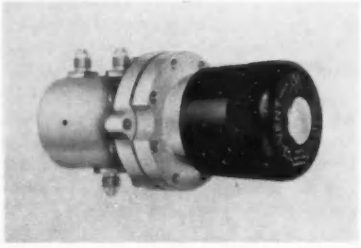
of two or more wires are available with screw contact for No. 18 through No. 8, or clamp contact for No. 22 through No. 10 wire. Strap screw contacts for terminal-ended or looped wires accommodate either a $\frac{5}{16}$-in. or narrower ring, or a spade terminal for No. 6 or larger stud. Contacts are on $\frac{7}{16}$-in. centers.—Buchanan Electrical Products Corp., Hillside, N. J.

Circle No. 39 on reply card

VENTURI RING MOUNTS

A new series of 4-, 8-, and 10-in. axial flow fans is now available. Each comes complete with a lightweight aluminum venturi ring that permits direct mounting against enclosures, cabinet walls, or dust filter boxes. Designed for military or commercial requirements, units are available for 50-, 60-, or 400-cycle operation.—Ashland Electric Products, Inc., Long Island City, N. Y.

Circle No. 40 on reply card



FOR HIGH PRESSURE

Instead of spring mechanisms, the new RV 2$\frac{3}{4}$-in. dome-loaded pressure reducer uses gas pressure for hand operation or three 18- to 30-vdc solenoids for remote control. It not only eliminates tiresome cranking, characteristic of existing hand loaders, but it offers wider inlet and outlet pressure ranges, is more compact, and lends itself to applications in pneumatic systems requiring "programming". Once the unit is set there is no bleed or leakage. Built-in relief valves eliminate the possibility of over-pressurization. With inlet pressures of 500 to 4,500 psig, outlet pressures range from 50 psig to within 50 psig of the inlet pressure.—Marotta Valve Corp., Boonton, N. J.

Circle No. 41 on reply card

WHAT'S NEW

(Continued from page 50)

place in one part of the U.S. as a result of a weapons-development program, thus bearing out, in large part, some of AS's predictions.

This boom is, of course, in Florida, whose Cape Canaveral is the site of recent missile launchings. In an area which includes Daytona Beach, Orlando, and Melbourne, everything, but everything, seems to have expanded. This means banks, sports industries, real estate, communications facilities, air freight (up 131 percent), building permits, sales taxes, newspaper sales, adult education, etc. Biggest representative of the new era here is The Martin Co., which is building two missiles (the Bullpup and the Lacrosse) and a missile fire-control system, in a big new plant near Orlando. Martin lays claim to 29 of the 31 enrolled in a new business administration course at Rollins College in Winter Park.

Armour Did $14 Million Worth of Research in 1957

In most annual reports the stress is, of course, on sales volume, but occasionally one comes along that plays up another barometer of success. Armour Research Foundation, whose most important commodity is research, has submitted one of these.

ARF's research volume last year was $14,067,534, which represents an increase in industrial, governmental, and overseas projects of more than 18 percent. Behind this increase was a new peak (734) in domestic projects (404 industrial and 330 governmental), a 4½-percent gain in expenditures for self-sponsored research and for research services benefiting the general public, and a new high in personnel. The 53 who joined the payroll since the beginning of last year swelled ranks to 1,290. Most of them were added to the professional staff, which now totals 867.

One of ARF's most interesting overseas projects is the so-called European Technical Observation Group plan, and it is exactly what its name implies. Because of it, 20 American industrial companies are getting a beeline into what makes European technology tick. The way it works is this: Five ARF technologists, headed by Herbert B. Gausebeck, manager of European operations, tour the continent looking for developments of potential value in the American market. Each technologist represents a differ-

ent field—mechanical engineering, electrical engineering, chemistry, chemical engineering, and metallurgy—and each field is represented back home by four of the 20 sponsoring American companies. Since the program started, a lot of worthwhile information has been exchanged about product lines, engineering, and research.

Grace Forms Silicon Maker; Sperry Rand Enters Market

New developments in silicon business—direct results or not of recent price decreases (CtE, Jan., p. 56)—continue to mount. One of the latest is the establishment of a silicon-making subsidiary in Puerto Rico by W. R. Grace & Co., the big, diversified company with major chemical interests, and the French chemical and metallurgical concern, Compagnie de Produits Chimiques et Electro-Metallurgiques Pechiney. Grace's subsidiary Grace Internacional will hold the majority stock interest in the new company, International Metalloids, Inc., and Pechiney, which is already producing silicon on its own in France, will hold the rest.

When it gets up full steam (expected time: mid-1958), International Metalloids will turn out about 20,000 lb of high-purity silicon a year. Overseeing this production will be three Grace men: Marlin G. Geiger, executive vice-president in charge of chemical divisions, and now president and chairman of the board of the new concern; Lewis C. Reid, formerly industrial chemical sales manager of Grace's Davison Chemical Div., who becomes vice-president of International Metalloids, and Samuel C. Streep, formerly senior development engineer of Davison, named IM vice-president and general manager.

• **$360 a good price**—Grace officials emphasize that the price per pound which they had set for their new company's brand of silicon, $360, was not the result of any influence by recent market changes, but was simply that price that seemed to fit the product and its quality.

Another new entry, the silicon-producing division established by Sperry Rand Corp. in 1956, has placed its first transistors and silicon diodes on the market. This is the Sperry Semiconductor Div., which Samuel M. Grafton manages with the help of marketing specialist Arthur M. Varnum, sales program director, and nine sales offices in the U.S. The

principal emphasis is on production of new types of semiconductors, especially the hard-to-manufacture types needed in special missile equipment. So far 17 kinds have been developed.

Finally, there is a new company in Saxonburg, Pa., doing business under the name of Single Crystal Corp. of America. Siccoa is growing single crystals of various materials for electronic, optical, and nuclear applications, and conducting research into problems of solid-state physics brought to it by industry and the government.

New Companies in the Field

Quan-Tech Laboratories, to produce power supplies, amplifiers, and other electronic equipment—in Morristown, N. J. General manager is John M. van Beuren, one of the founders and a former president and chairman of Measurements Corp. He and Alan P. Stansbury, Quan-Tech's chief engineer, come to the new company from the Thomas A. Edison Laboratory in West Orange, N. J. Stansbury, who was head of the Electronics Section there, previously was with the Dept. of Terrestrial Magnetism of the Carnegie Institution and the Central Radio Wave Propagation Laboratories of NBS.

Townsend Engineered Products, Inc., a new R&D subsidiary of Townsend Co.—in Santa Ana, Calif. President is G. O. Noville, formerly president of G. O. Noville & Associates, one of the two Townsend units making up the new concern. The other: the Armament Components Div. Under Robert H. Aaron, Samuel L. Sola, and Charles F. Schultz, all former Noville and Armament Components Div. officials, TEP will engineer equipment and components for the aircraft, automotive, petroleum, ordnance and transportation industries.

Electro Precision Corp., headed by a jet-engine specialist who was formerly with the Control Section of General Electric's Aircraft Gas Turbine Div.—in Arkadelphia, Ark. John Hosemann, the ex-GE man, was first manager of marketing, then in charge of engineering and manufacturing of jet-engine variable-area inlet-duct controls in AGT Div. Before going to GE, he was with the Clevite Research Center and Electronic Associates, Inc. The board of the new company includes Waldo Kliever, the former director of research for Minneapolis-Honeywell Regulator Co., who is now a consultant in the automatic control field. In line with its an-

nounced intention to develop special-purpose process-control systems, Electro Precision is bringing out a pressure-regulating valve that is actually a packaged system containing an electric valve, a controller, and a pressure transducer. The system is able to control pressure as a function of several process variables.

Data-Control Systems, Inc. formed to apply the "systems approach" to measurement, computing and data-handling, and telemetry, under a group of executive engineers headed by Robert J. Jeffries, president of ISA—in Danbury, Conn. Jeffries, who was most recently assistant to the president of Daystrom, Inc., is an educator and consultant. With him in the new venture are Gunther J. Martin, formerly with Schlumberger Well Surveying Corp., who is director of technical developments; Weems E. Estelle, the former manager of engineering for Thomas A. Edison, Inc., named supervisor of automatic control programs, and Raymond A. Runyan, head of telemetry development. Runyan has achieved a reputation in telemetry design as a result of his work with such companies as Electro-Mechanical Research, Boeing, North American Aviation, and Pratt & Whitney.

Drexelbrook Consulting Service, which, under Frederick L. Maltby, formerly technical director of Robertshaw-Fulton Controls Co., will assist manufacturers of measuring, recording, and control instruments, make new product studies for military suppliers, and instruct insurance companies in the use of electrical instruments for explosive areas—in Abington, Pa. One of Drexelbrook's specialties: assistance in shifting from military to commercial manufacture (and vice versa) of automatic control devices. Maltby, who was also technical director of the Bristol Co., heads the Committee for Hazardous Area Instrumentation of the ISA.

Control Instruments Laboratory, to produce custom-designed process equipment, control components, and systems—in Newton, Pa. Director is Nathaniel Brewer, the former vice-president of engineering and research of Fischer & Porter Co. F&P is scheduled for the lion's share of the new company's technical know-how.

Hyperion, Inc., which will manufacture ac and dc supplies and ac to dc converters with transistorized circuitry—in West Newton, Mass.

Electro-Contacts, Inc., manufacturer of slip rings for strain gages,

WHAT'S NEW

thermocouples, high-voltage supplies, and pulsing, time-sharing, and sampling switches—in Osterville, Mass.

Annual Reports

The following annual financial reports are from companies whose fiscal years ended between June and September 1957. Reports from other companies whose fiscal years closed at about the same time appeared in the December issue, page 52.

North American Aviation—Net sales up from $913,981,913 to $1,243,767,438; net income up from $28,760,962 to $33,864,462; backlog down from $1,285,000,000 to $581 million, the lowest point since 1951. Though net income and net sales (at the billion-dollar mark for the first time in the company's history) were at record highs, the former represented a smaller percentage of net sales than it did in 1956. The reason: the continuing trend toward cost-type contracts, under which lower profit rates are generally negotiated. The company expects last July's termination of the Navaho missile program to be felt this year in a great drop in net sales. The estimated figure, $700 million, is far below even 1956. As far as the shallow backlog goes, Chairman J. H. Kindelberger expresses little concern. The long-range outlook, he says, is excellent because of the nation's continuing security requirements and North American's proven ability to meet these requirements, and because of the company's deliberate diversification. Proof: 1957 sales by nonaviation divisions, more than double what they were in 1956, accounted for more than half the increase.

Packard-Bell Electronics Group—Sales up 13.5 percent to $32,262,878; net income down from $862,356 to $704,447. A big factor in the jump in sales was the 76-percent increase chalked up by the Technical Products Div., whose advanced electronic equipment brought in $12,152,386, as compared with $6,884,022 in 1956. The drop in net income was due to high labor and material costs, and to increased R&D expenditures.

Radiation, Inc.—Sales more than doubled ($3,473,763 in 1956; $7,919,034 in 1957); net profit up from $218,619 to $343,017; retained earnings up to $662,672.

Snyder Tool & Engineering Co.—Sales up to $15,448,055, nearly $6 million more than any previous year (1956: $9,708,323); net profit $528,120, up from 1956's $454,377 but

WHAT'S NEW

down from 1955's $592,072. Reason: smaller profit margins than expected, due to a greater use of sub-contractors, a sharp increase in wage rates, and an inadequate pricing structure.

Fattenings

Data Storage Devices Co. (magnetic recording heads for ground and airborne magnetic tape instrumentation systems) by **Midwestern Instruments, Inc.**, which will move the Van Nuys, Calif. company to Tulsa and operate it as a division under former DSD president Francis A. Oliver, who becomes a vice-president.

Millivac Instrument Corp. and **Volkers & Schaffer, Inc.**, both of Schenectady, N. Y. (electronic instruments for measurement and control) by **Cohu Electronics, Inc.**, which will combine the two companies into a Millivac Div. Walter Volkers, president of both companies, who becomes president of the new division and a vice-president of Cohu, is said to be an international authority on electronic instrumentation.

George K. Nankervis Co. (automotive and aircraft testing equipment and precision flow-measurement instruments) by **Peninsular Metal Products Corp.** of Ferndale, Mich.

Kurman Electric Co. (commercial and military relays and switches) by **Norbute Corp.**, which will operate Kurman as a division under two of its own executives.

Elsin Electronics Corp. of Brooklyn, N. Y. (electronic, mechanical, and electromechanical equipment) by **General Transistor Corp.**, which has named Norman Jacobson, formerly director of contract administration engineering for Lewyt Mfg. Corp., president of Elsin. George Ivandus and Edward Berzins remain as vice-presidents for manufacturing and engineering, respectively.

Reinhold Engineering & Plastics Co., Inc., of Norwalk, Calif. (plastics for the aircraft and chemical industries) by **Haveg Industries, Inc.**, pioneer developer of chemical corrosion resistant plastic equipment.

Nader Mfg. Co. and **Motordyne, Inc.**, both of Monrovia, Calif. (rotary electric equipment, such as dc and ac fractional-hp motors, blowers, and governors; and transistorized products, including inverters, converters, dynamotors, digital counters, and power supplies)—a merger. Surviving company is Motodyne, Inc. President and chief engineer is Joseph Nader.

(Additional What's New, page 175)

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CONTROL ENGINEERING
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CONTROL ENGINEERING
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(100) PORTABLE POTENTIOMETER. Technique Associates, Inc. Bulletin T-57, 6 pp. Describes the Thermotest I, a new portable potentiometer-pyrometer, and suggests 18 applications in laboratory or plant testing. A condensed list of specifications follows a discussion of special features such as a smooth vernier drive, magnified divisions, and an automatic cold junction.

(101) BASIC CONTROLS. Powers Regulator Co. Catalog, 96 pp. Covers more than 34 basic types of industrial temperatures and pressure controls. Included are self-operating regulators, water mixing equipment, pneumatic control instruments, indicators and recorders, control valves, and pneumatic motors.

(102) TRANSISTOR DATA. Atlantic Research Corp. Technical Note No. 2, 2 pp. Reports the results of studies made to determine the pressure response of piezoelectric ceramic transducers. Graphs are used to illustrate calibration curves for four of the manufacturer's pressure transducers. Figure 3 is a graph showing the relative charge sensitivities of two piezoelectric ceramics.

(103) FERRITE MAGNETICS. General Ceramics Corp. Bulletin F-557, 8 pp. Subjects covered include the nature of ferrites, their production, advantages and limitations, applications, and the shapes and sizes available. A condensed table lists specifications of various Ferramic bodies.

(104) MOTORS AND CONTROLS. Reliance Electric & Engineering Co. Bulletin A-2501, 8 pp. Photos and captions describe a complete line of ac and dc motors, gear-motors, motor-generator sets, motor controls, and complete packaged mechanical and electronic adjustable-speed drives.

(105) OSCILLATOR CONTROLS. James G. Biddle Co. Bulletin 34-10, 12 pp. Provides some useful technical information on the application and operation of Frahm resonant reed oscillator controls. Illustrations include block and circuit diagrams, a cutaway view of the Type ROC control, and drawings showing the case dimensions and internal wiring.

(106) AUTOMATIC REGULATOR. The Superior Electric Co. Data Sheet SE-L3579, 1 page. Describes the features and principal specifications of a new electromechanical, automatic voltage regulator for 400-cycle applications. Both electrical characteristics and physical dimensions are included in the specifications.

(107) INDUSTRIAL SOLENOIDS. W. L. Michael, Inc. Catalog, 4 pp. Lists five basic types of solenoids suitable for a wide variety of industrial applications. Tables provide a ready reference to the forces developed by each type. Readings for both ac and dc are provided, as well as for continuous and intermittent duty.

(108) PAPER-TAPE HANDLING. Whiteford Laboratory. Bulletin, 4 pp. Illustrates the operation and application of two new tape handling devices, a motor-driven winder and a balanced unwinder. Covers movement, positioning, tension, capacity, motive power, speed, and maintenance of the winder.

(109) VARIABLE TRANSFORMERS. Standard Electrical Products Co. Chart, 4 pp. Interchangeability chart provides data on the type and output amperage of Adjust-A-Volt, Powerstat, and Variac variable transformers. It covers both manually operated and motorized units and should prove useful to design engineers interested in industrial, commercial, or military applications.

(110) FREQUENCY METERS. Varo

Mfg. Co. Brochure, 8 pp. Covers a variety of 400-cycle frequency meters for different applications. A convenient chart on the last page summarizes the specifications of each model.

(111) MINIATURE CONNECTORS. DeJur-Amsco Corp. Brochure, 6 pp. Gives specifications, diagrams, and some general descriptive data on the manufacturer's Series 250 miniature rectangular power connectors. Short table covers electrical and mechanical ratings, while drawings show outline and mounting dimensions.

(112) TRANSISTOR DATA. Kahle Engineering Co. Brochure, 8 pp. Six pages of this new bulletin provide complete, up-to-date technical specifications and application data on the 489 transistors now available. Included are more than 170 new types introduced during recent months.

(113) PNEUMATIC CONTROLLERS. Fischer & Porter Co. Catalog 53P-4000, 12 pp. Discusses the operation and design features of the company's Model 53P motion-balance pneumatic controllers. A unique regenerative feedback circuit, integrated accessories for case-mounted controllers, and plug-in controllers for use with miniature instruments are also described.

(114) ELECTRICAL CONTROLS. Assembly Products, Inc. Bulletin 106, 12 pp. Photos and circuit diagrams supplement the descriptive information on a line of simple, all-purpose electrical controls called Versatrols. Bulletin explains applications of the more common Versatrol circuits, both automatic and limit, including a new overload control.

(115) PRESSURE TRANSMITTER. Fischer & Porter Co. Catalog 10B1465, 4 pp. Lists the chief design features of a new differential pressure transmitter and describes its operating components. A cutaway view, in color, illustrates the internal construction. Last page covers specifications and performance data.

(116) LEVEL MEASUREMENT. Instrument Div. of Robertshaw-Fulton Controls Co. Booklet, 16 pp. Provides a detailed description of several capacitance-type level measurement and control systems. Applications covered include the quantitative measurement and control of granular solids, liquids, and powders, as well as interface control.

(117) ACCELEROMETER LINE. Donner Scientific Co. Data File 410, 4 pp. Contains photos, dimensional drawings, specifications, and other descriptive material on a complete line of vacuum-tube and transistorized accelerometers. Operating principles are explained and a variety of applications discussed.

(118) SPEED CONTROL DRIVES. Clark Controller Co. Bulletin 20,000, 8 pp. Explains the basic circuits and variations available in a complete line of packaged drives for equipment requiring adjustable speed or speed synchronization. Describes a number of typical applications, and points out special advantages.

(119) INDUSTRIAL THERMOMETERS. Weksler Thermometer Corp. Catalog No. 125A. Contains all pertinent engineering data relating to complete line of industrial thermometers. Gives case and socket dimensions, standard temperature ranges and scale divisions.

(120) NEW PHOTOMETER. Phoenix Precision Instrument Co. Bulletin JM-1000-C, 8 pp. Illustrates and describes a new portable air pollution photometer. Covers the principles of operation, and presents a simplified schematic drawing of the complete optical system and smoke chamber. Also has some data on such special accessories as indicating meters, two-pen recorders, and ratio recorders.

(121) ACCURATE PRESSURE TRANSMISSION. Computer Components Div. of International Resistance Co. Form S-051, 2 pp. Describes the Series 70-2000 Compu-Tran pneumatic transmitters designed for low cost and suitable for multiple-pressure scanning and alarm systems. Mechanical and electrical specs follow a section on the pressure elements.

(122) COMPANY LINE EXPANDS. Beckman/Berkeley Div. of Beckman Instruments, Inc. Short form catalog C-704, 8 pp. Contains data on some 20 new instruments that have recently been added to the expanding line. Both digital and analog devices are included.

(123) PANEL INDICATORS. Hagan Chemicals & Controls, Inc. Bulletin MSP-121, 12 pp. Illustrated with both photos and drawings, this bulletin covers a complete line of space-saving, panel-mounted indicators for draft, pressure, and temperature. These units are also available for services as receivers, taking signals from pneumatic transmitters to indicate flow, level, density, high pressure, etc.

(124) PLUG-IN AMPLIFIERS. Universal Transistor Products Corp. Bulletin, 4 pp. Shows how a couple of tough design problems were licked through use of transistorized plug-in amplifiers.

(125) COMPUTER ELEMENTS. Ransom Research. Bulletin C-24, 8 pp. Covers transistorized, plug-in computer elements for the design of industrial counting and data processing equipment, logical control systems, digital systems, and computer logic. Features includes all-transistor design and low power consumption.

(126) DIAPHRAGM-OPERATED VALVE. Seely Instrument Co., Inc. Bulletin V-8, 4 pp. Direct-acting, reverse-acting, and three-way diaphragm valves are covered in this bulletin. Diagrams showing typical applications accompany the descriptions. Includes notes on design, construction, maintenance, and operating pressures.

IMPORTANT MOVES BY KEY PEOPLE

Polaris Contract Prompts Top Lockheed Assignments

Lockheed Aircraft's Missile Systems Div., in receipt of the Navy's Polaris ballistic missile contract, is battening down the hatches and assigning stations for the work ahead. Louis Strauss, the former chief of the Aeronautical Mechanical Engineering Div. of the Naval Air Missile Test Center at Point Mugu, Calif., who has been acting manager of the division's Control Systems Dept., has been named manager. He will direct development of the Polaris's control system.

At the same time Irvin D. Black, a former government advisor on rocket fuels and propulsion, joins the division as staff engineer in the Airframe Propulsion & Internal Systems Dept. Black's experience in rocketry goes back to 1945, when he "researched" the German V-2 rocket for the Air Force. In 1954 he left the government to establish his own consulting service. He, too, will concentrate on the Polaris.

South of San Francisco, in the Santa Cruz mountains, the division is putting the finishing touches to its 4,000-acre missile test site and staffing toward an expected payroll of between 150 and 180. The administrative area has already been completed, the ordnance area almost so. Other work is progressing on a control room and three test cells in the component test area, a sewage-disposal system, and a water-supply system. There will be no flight testing at the site, according to A. L. Hubbard, test base manager.

Barnes Unveils New Firm; Moon Still on His Mind

John L. Barnes, whose departure from his own Systems Laboratories Corp. last July stirred up quite a bit of interest and speculation in engineering and business circles (CtE, Aug. '57, p. 46), is back in the news as president of a brand new company, Systems Corp. of America. His disappearance last summer, though still somewhat of a mystery, seems to have been due to a disagreement with his partners over the technical obstacles standing in the way of space travel. Now it is disclosed that he has sold his stock in SLC and is as eager as ever to reach the moon.

Systems Corp. of America will be concerned with consulting and research in interplanetary travel and

WHAT'S NEW

"environmental measurements" beyond the atmosphere. Its home, at least for the time being, will be in West Los Angeles. It has not been determined whether Barnes will continue at the UCLA as professor of engineering.

Other Important Moves

▶ **Van Zandt Williams,** considered a leading authority on infrared spectroscopy, has been named executive vice-president of The Perkin-Elmer Corp. He advances at P-E from general manager of the Instrument Div., a position he held since 1956. Before that he was a vice-president and director of sales and research. He joined P-E in 1948 from American Cyanamid Co. During the war he worked on certain aspects of the Manhattan Project.

▶ **Walter Kudlaty,** promoted to chief design engineer of the Miller Fluid Power and Tru-Seal divisions of Flick-Ready Corp., has been with the company since 1949. He is author of the text on fluid power, *Hydraulics for Machine Tools*, and chairman of the Terminology Committee of the National Fluid Power Association. He is also a senior member of the American Society of Tool Engineers.

▶ The new proposals coordinator of Consolidated Electrodynamics Corp. is **Martin V. Kiebert,** the former director of electronics for the Miami Shipbuilding Corp. and a man with an interesting background in control. He has been director of R&D for TeleDynamics, Inc.; director of the Special Products Research Laboratory of Bendix Aviation Corp.; chief engineer of the Tuner Div. of P. R. Mallory Co.; assistant to the chief engineer of Convair's Guided Missiles Div., and director of research and electronics for Applied Research, Inc. During the war he was head of the Special Weapons Branch of the Bureau of Aeronautics.

▶ **Jackson K. Lightfoot,** the former chief engineer of Omark Industries of Portland, Ore., has been named chief engineer of the Missile Products Div. of Beckman & Whitley, Inc. Lightfoot has also been with Food Machinery & Chemical Corp. and Magnuson Engineers. He will be responsible for all work in connection with explosive-actuated devices.

▶ The new head of the Circuit Research Section in the Control Div. of Magnetics, Inc., is **Roland L. Van Allen,** who comes to the division from the Naval Research Laboratory in Washington, where he helped design the telemetering system for the Vanguard earth satellite. At Control, he will do R&D work in industrial transistor-magnetic circuitry.

▶ Norden-Ketay Corp. has appointed **Wladimir A. Reichel** senior vice-pres-


Van Zandt Williams


Walter Kudlaty


M. V. Kiebert


J. K. Lightfoot


R. L. Van Allen


W. A. Reichel

LINEAR ACCELEROMETERS

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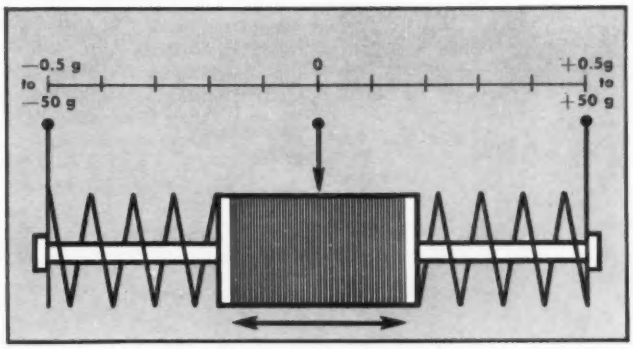
Shown Actual Size

Honeywell Linear Accelerometers sense positive or negative accelerations or both in either the vertical or horizontal plane. Designed for use in aircraft and missiles, they are available in a variation of ranges from ± 0.5 g to more than ± 50 g's depending upon requirements. These units consist of a centrally located mass restrained by coil springs and supported on a linear-type ball-bearing. Any movement of the mass on either side of the null displacement position is measured by a potentiometer pick-off, providing a high level output signal. Viscous damping is incorporated for improved dynamic response. Zero cross-coupling is inherent with this true linear non-pendulous design. (Cross-coupling is defined as a change in output signal caused by an acceleration applied from any direction in a plane normal to the sensing axis) Excitation may be as high as 100 volts (A-C or D-C) depending on the potentiometer resistance. *Write for Bulletin LA . . .* Minneapolis-Honeywell, Boston Division, Dept. 34, 1400 Soldiers Field Road, Boston 35, Mass.



- LINEAR RESPONSE
- D-C OUTPUT SIGNAL
- VISCOUS DAMPING
- HERMETICALLY SEALED
- EXTREMELY RUGGED
- WEIGHT: APPROXIMATELY 0.9 POUNDS
- ENVIRONMENT: MEETS MIL-E-5272A

MINNEAPOLIS **Honeywell** H HONEYWELL

BOSTON DIVISION

Write for Bulletin LA

WHAT'S NEW

ident. Reichel comes from General Precision Equipment Corp., where he was senior vice-president for engineering and was largely responsible for the growth of GPEC's Kearfott Co. into a $55-million-a-year operation. During the war, as director of engineering for Bendix's Eclipse-Pioneer Div., he did some outstanding work in motors, synchros, and gyros. His more recent contributions have been in the field of inertial navigation. He is a consultant to the chief of naval operations.

▶ Two appointments at Associated Spring Corp.'s research center in Bristol, Conn., involve **William R. Johnson,** named chief research metallurgist, and **Richard J. McCluskey,** chief machine design and development engineer. Johnson, whose area will be basic research in spring design and

R. J. McCluskey

W. R. Johnson

fabrication, has been at ASC's Wallace Barnes Div. since 1953. Before that he was with Crucible Steel Co., Metalab Co., and Standard Steel Works. McCluskey comes to the company from The Stanley Works of New Britain, Conn. He will supervise R&D work in spring design.

▶ **Herman R. Shuart** has been elected executive vice-president, and **Robert N. Brown** vice-president and director of engineering, of Kearfott Co., Inc. Shuart was vice-president for engi-

H. R. Shuart

R. N. Brown

neering since the beginning of last year, and before that director of engineering and chief engineer. He joined Kearfott in 1945, coming from Arma Corp. and Bendix Aviation. Brown, director of engineering since last year, came to the company in 1946. He was previously with Westinghouse Electric Corp.

New "OFF THE SHELF" component service cuts system development time by MONTHS!

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You and your company can take advantage of this new service. You can get started today, by writing for your free copy of our Mechatronic Development Apparatus Catalog—MDA-58. When it arrives, you select the components you need, send in your order, and receive your shipment within a few days.

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ABSTRACTS

Automatic Programming

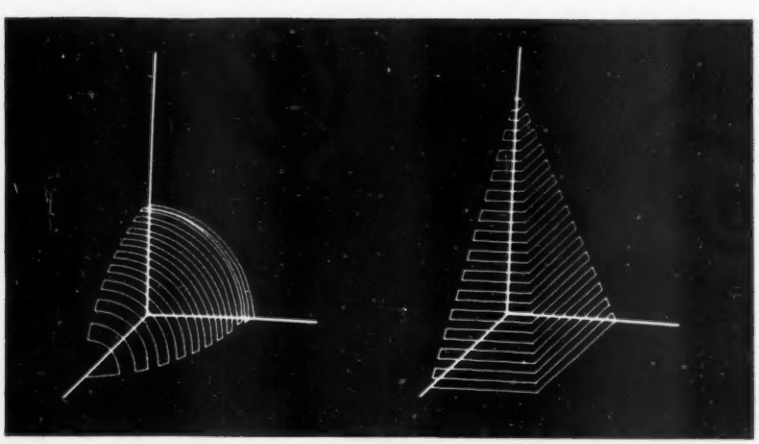
From "Some Recent Developments in Automatic Programming for Numerically Controlled Machine Tools" by Douglas T. Ross, head of the Computer Applications Group, Servomechanisms Laboratory, MIT. Paper presented at the Third Annual Contour Machining Conference, Los Angeles, Calif., Oct. 23-24, 1957.

To get the most from a numerically controlled machine tool, it is necessary to find some means for passing directly from the designer's plans to the detailed numerical instructions needed to produce the part; that is, by-passing the expensive stage of manual programming, a stage that tends to becloud the economic justification of numerical control. This is the goal of automatic programming. Although it will be some time before the full potentialities of this new technology can be realized, members of the aircraft industry are making some headway with a limited automatic programming system for contour machining.

As defined in this paper, automatic programming entails the generation of detailed, specific instructions, in the language of a general-purpose digital computer, from statements made in a specially designed, easy to use, less specific language. In 1955, a pilot program written by Arnold Siegle of MIT and operated on the Whirlwind I computer automatically produced punched paper control tapes for the MIT numerically controlled milling machine. The program involved arbitrarily two-dimensional parts that could be specified by straight lines and circles. One major advantage of the system was that it could be made to assist the part programmer in stating his problem. Some of the straight lines and circles were constructed implicitly by statements in the language itself, and not stated explicitly as inputs to the problem. This is one of the most powerful aspects of automatic programming.

Initial success of this pilot program led researchers into the problems of programming for three-dimensional parts, to be produced on three- and five-axis numerically controlled machines. The name APT (Automatically Programmed Tool) System was coined for the overall development, and numbers were given to the successive stages or levels of refinement. APT I, similar to the pilot program, involves a minimum of automaticity—the computer acts as a calculation aid by means of a library of subroutines. The next level, APT II, allows the programmer to specify and produce a part by statements made in terms of space curves rather than individual points. The highest level so far determined, APT III, involves statements made in terms of entire portions of the machined surface. In all three systems, the computer's function is to process the statements (in the convenient APT language) into detailed numerical statements using the language of the machine tool director.

In all three APT systems an auxiliary output from the computer, in an appropriate language form, permits the human programmer to monitor the system performance and correct any mistakes he may have made. One such output could be an oscilloscopic three-dimensional picture of the part being made. Two examples of this



Oscilloscopic pictures permit human monitoring of an automatic program.

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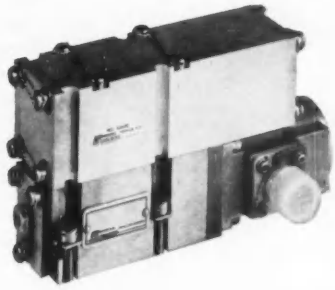
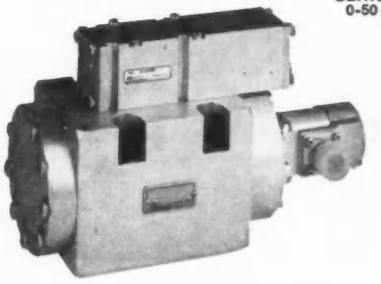


SERIES 200
0-10 gpm

SERIES 300
0-50 gpm



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Sanders Electro-Hydraulic Servo Valves are based on the reliability-proved "BOOTSTRAP" two stage internal force feedback principal. This design converts low input into powerful thrusts, while providing high internal stiffness of control.

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TYPICAL SPECIFICATIONS

	SERIES 100	SERIES 200	SERIES 300	SERIES 500
Flow Range (GPM at 1000 psi ΔP)	0-5	0-10	0-50	0-200
Supply Pressure (psi)	200-3000	200-5000	200-3000	500-3000
Overall Size (inches)	2¼ x 2¼ x 2½	5¾ x 1½ x 3	8⅜ x 3¼ x 5⅛	15¼ x 6½ x 4¾
Approximate Weight (pounds)	1.0	3.6	7.5	35.0
Nominal Input Power (watts)	0.1	0.2	1.0	1.0
Coil Resistance (ohms /coil)	100-3000	100-3000	100-3000	100-3000
Amplitude Ratio	–3db at 150 cps	–3db at 80 cps	–3db at 60 cps	–3db at 30 cps
Phase Lag	90° at 150 cps	90° at 80 cps	90° at 60 cps	90° at 30 cps

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ABSTRACTS

type output are shown in the figure on page 180.

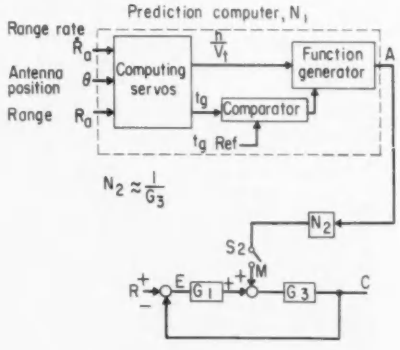
Foremost problem of automatic programming is language design, or determining a vocabulary and rules for making statements to the system that will convey the design problem in a complete but unsolved form from the human mind to the computer. Much research remains to be done in this area.

Prediction Computer Applied

From "Reduction of Control Loop Errors With a Prediction Computer" by G. S. Axelby and R. H. Plath, Air Arm Div. of Westinghouse Electric Corp. Paper presented at the AIEE Conference on Computers in Control, Atlantic City, N. J., Oct. 17, 1957.

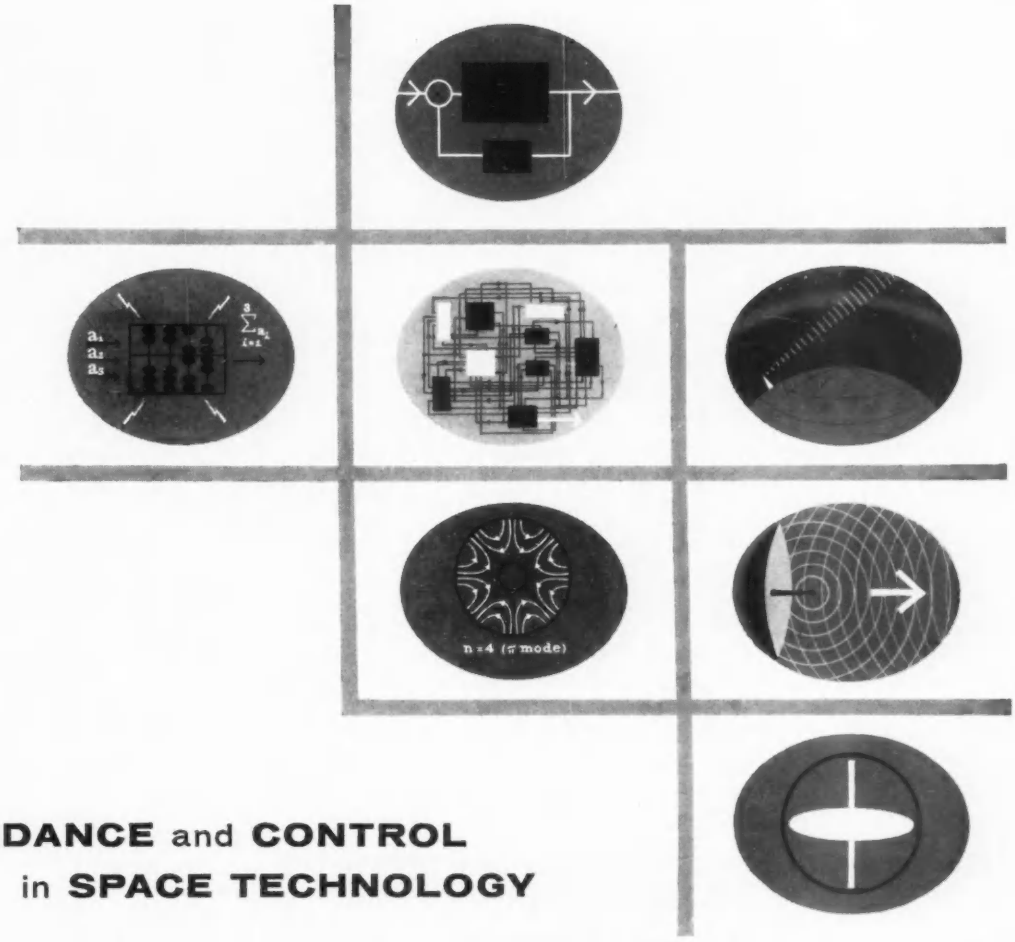
This paper describes the development of an optimum, realizable tracking servo that will maintain a specified minimum rms rate error due to signal and noise components. The system, described in terms of its bandwidth, may be defined as one requiring a minimum amount of noise reduction, for the given signal and noise input, to obtain a specified minimum error.

For particular inputs, however, the required bandwidth of conventional tracking servos may not be realizable if the desired error is small. The authors therefore propose the use of a prediction computer to augment the input signal and make the system realizable. An hypothetical tracking problem is set up and analyzed. The figure illustrates a possible method of



Possible computer arrangement

mechanizing a prediction computer, N_1, and a compensating network, N_2, for this analysis. Design and accuracy of the computer are discussed, along with an indication of the computer's effect on tracking bandwidth, noise reduction, and realizability.



GUIDANCE and CONTROL in SPACE TECHNOLOGY

It is becoming increasingly apparent that many of the techniques and analyses, and much of the equipment, developed for the present Air Force ICBM-IRBM programs will have a wide future application in space technology. For instance, many of the guidance and control techniques for ICBM's are applicable to the space vehicles of the near future.

An important element of these applications is precision. The precision required of the guidance and control system for vehicles aimed at the moon or one of the planets is not substantially greater than that required for the Air Force ICBM-IRBM programs. And, the precision needed to guide a vehicle into a near-circular orbit of Earth is even less than that required for ICBM's.

The problem of communication with lunar and planetary vehicles is, of course, made more difficult by the much greater distances involved. This, however, is not an insurmountable difficulty if today's trends continue in the use of higher transmitted power, narrower communication bandwidths and amplifiers with very low noise-figures.

The problems of operating electronic equipment in the space beyond our atmosphere are already encountered on present ballistic missile trajectories. The principal difference in the case of space vehicle applications is the requirement for longer equipment lifetimes. Electronic equipment and power supplies will have to last for several hours or days or weeks, instead of a few minutes, under conditions of vacuum pressure, zero "g" fields, and bombardment by micrometeorites, high-energy particles, and radiation.

The preceding examples serve to illustrate some of the ways in which the ICBM-IRBM programs are advancing the basic techniques of space technology.

Since 1954, Space Technology Laboratories has been providing over-all systems engineering for these programs. Both in support of this responsibility and in anticipation of future system requirements, the Laboratories are presently engaged in a wide variety of advanced analytical and experimental work directed toward the exploration of new approaches in space vehicle electronics, propulsion, and structures.

The scope of STL's work requires a staff of unusual technical breadth and competence. Engineers and scientists who are interested in advanced experimental development projects (as distinct from development for manufacturing, in which STL is not engaged) are invited to investigate the many opportunities on the Laboratories' Technical Staff.

SPACE TECHNOLOGY LABORATORIES

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NEW BOOKS

A Programming Manual

DIGITAL COMPUTER PROGRAMMING. *D. D. McCracken, Manager, Training Computer Dept., General Electric Co. vi + 253 pp. Published by John Wiley & Sons, Inc., New York, 1957. $7.75.*

It is very fortunate that the first book on general digital computer programming is lucid, broad, and authoritative. We have been spared the quandary that comes with acquiring one book "because it's all that's available", only to find we must add several more at six-month intervals. This addition to the General Electric Series will remain a valuable text and reference.

The author has written the book "for people with no previous knowledge of computing who want to know how to prepare the detailed 'instructions' for the computer, as well as for people whose work is so closely related to computer applications that they need to know what is involved in programming". To this reviewer, the book presents an interesting means by which any control engineer can familiarize himself with the practical capabilities of digital computers and some of their operational and organizational aspects. Persons already working with a specific machine will find the book valuable as a reference on particular topics.

For illustrative purposes the author introduces TYDAC, a hypothetical TYpical Digital Automatic Computer; sample TYDAC programs are used throughout. These will help the student, but need not be followed in detail by one seeking a reference on a particular subject. Chapter headings show a broad coverage, from computing fundamentals to automatic coding, in which the computer is made to do part of the programming. Problem exercises are presented after all but three of the 18 chapters.

The book might have had more appeal for some readers if it contained more material on the smaller drum-type machines. TYDAC is most typical of a large, decimal, instant-access machine having many commands and and extensive operator console. And though practically all of the material applies to smaller machines, their special aspects—a limited number of commands, unique storage characteristics, and their reliance on systematic storage and interpretive routines—could have been treated at more length. Also, while the appendix on minimum-

analog computor with a NEW TWIST

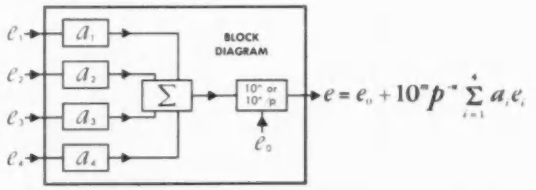
Just twist the knob... decade settings simplify precise parameter programming

In the all-new Philbrick Model K5-U Universal Linear Operator, decade settings replace the usual computing potentiometers to simplify precise parameter programming. Easy to interconnect and use, Model K5-U embodies a variety of operations in one compact, chopper-stabilized unit. This fundamental building block of a general purpose analog computing system permits the analog computor user to extend his design and analysis facilities at reasonable cost.

The Model K5-U accepts up to four voltages and multiplies each by a constant, settable by decade switches to any positive or negative value between 0 and 11.10 in increments of 0.01. These weighted inputs are added together and the sum is then operated on in one of two general ways.

1. The sum may be multiplied by 0, 1, 10, 100 or 1000 and then have added to it a positive or negative index voltage, adjustable from 0 to 50.0 volts in steps of 0.1 volt.

2. The sum may be integrated using any of a wide range of available speeds, viz., 1, 10, 100 or 1000 radians per second. The output voltage may be held at any time, or it may be reset to an initial value which is determined by the index voltage decade setting. The SET-RUN-HOLD modes may be controlled either remotely or manually on the front panel.



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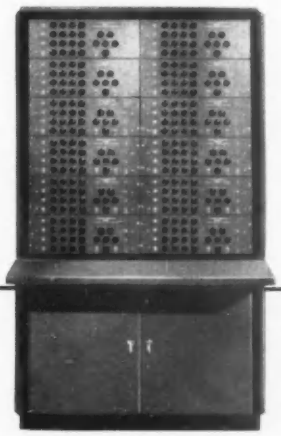

Model K5-U retains the convenience, economy and versatility of modular assembly.

NEW BOOKS

access programming does relate to drum machines, the subject could have been usefully expanded.

Any reader, however, will enjoy the wide perspective and the liberal inclusion of clear, sound advice on the many topics covered. The book reflects extensive knowledge and experience on the part of the author.

William S. Aiken
The Ramo-Wooldridge Corp.

Broad Look at Automation

AUTOMATION IN BUSINESS AND INDUSTRY. *Edited by Eugene M. Grabbe, Senior Staff Consultant, The Ramo-Wooldridge Corp. 611 pp. Published by John Wiley & Sons, Inc., New York City, 1957. $10.*

Based on an extension course given at the University of California, this book provides an opportunity for both management and engineering personnel to take a wide-angle look at what automation really means and how it is being applied today. Some 21 authors, experts in their respective fields, have contributed to this overall picture. Each reviews the developments in automation, instrumentation, and control in his own field, discusses present-day application, and provides the reader with some idea of what to expect in the future.

The book consists of 14 chapters, their sequence following that used for the lecture course. This, incidentally, makes the book quite attractive as a possible text for a similar course in other schools.

After a brief historical introduction and a few short chapters to familiarize the reader with the present status of automation, its language, and fundamentals, Harold Chestnut discusses the characteristics and use of feedback control systems. The first section of Chapter 5 defines the basic concepts of industrial instrumentation; another reviews the extent to which automation has been advanced in the process control field.

Chapters 6, 7, 9, and 10 cover the hardware, the electronic computing and data processing equipment available today. Included are analog computers, digital computers, analog-to-digital converters, and input-output devices. In Chapter 8, Univac's John W. Mauchly outlines the requirements of electronic data processing, discusses its economic justification, and suggests a variety of ways in which

Here G. D. Schott (right), Flight Controls Department head, discusses computer solutions of control and guidance problems with E. V. Stearns (center), Inertial Guidance Department head, and J. E. Sherman, Analog Computer Section head.

Lockheed Missile Systems announces new positions in

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Positions are open on the Sunnyvale and Palo Alto staffs for engineers possessing strong ability and interest in: Research and development of advanced flight control systems for controlling missiles and rockets; system synthesis by application of control system feedback techniques; analysis and design of nonlinear servo systems; development of transistor and magnetic amplifier techniques in the design of advanced flight control systems; analysis and simulation of the dynamic performance of the guidance – autopilot – airframe combination; development of systems utilizing advanced types of inertial and gyroscopic instruments; analysis and design of hydraulic servo systems for controlling missiles at high Mach numbers; environmental and functional testing of prototype flight control systems.

Inquiries are invited from engineers possessing a high order of ability. Address the Research and Development Staff, Sunnyvale 15, California.

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these systems are saving both time and money.

The next seven chapters (244 pp.) deal with concrete applications. Systems for office automation, flight control, factory automation, numerical machine-tool control, and computer control are described and illustrated. Here the advantages of multiple authorship become more apparent. It is difficult to believe any single author could have handled these diverse subjects with the consistent familiarity that is exhibited in each of these chapters.

In the last two chapters, the reader is given a pretty good idea of the economics involved in plant automation and what can be expected in the future as a logical result of systems engineering.

Admittedly not a technical treatment of the subject, the book probably contains enough details to satisfy any engineer looking for an overall picture of automation today. The lack of uniform style, which Grabbe admits to, seems to be far outweighed by the knowledge that the reader is getting the best available thoughts on each particular subject.

Books on Fluid Power

A BIBLIOGRAPHY OF FLUID POWER. *Compiled through the cooperative efforts of the Education Committee of the National Fluid Power Association. About 100 pp., looseleaf bound. Published by the National Fluid Power Association, Evanston, Ill., 1957. $2.*

Admittedly not comprehensive, this nevertheless valuable work represents a cross-section of the best literature available on fluid power.

Primarily, it classifies and describes those books that deal directly with the subjects of fluid power, hydraulics, and pneumatics. Books on the fringe of these subjects and handbooks containing only a few chapters on fluid power have not been included; nor, because of lack of time and space, have many worthwhile articles, papers, transactions, and pamphlets.

To make the insertion of future additions convenient, the book has been prepared in looseleaf form. The association hopes at a later date to issue a reasonably comprehensive bibliography of magazine articles and papers.

Following the body of the work are an alphabetical subject index and an alphabetical author-title index for easy cross-reference.

WHAT'S AHEAD: MEETINGS

FEBRUARY

American Institute of Electrical Engineers, Winter General Meeting, Hotel Statler Feb. 2-7

Flight Control Symposium on Panel Integration, sponsored by U. S. Air Force, Flight Control Laboratory WADC, and Cook Research Laboratories, Baltimore Hotel, Dayton, Ohio; program and reservations: John H. Kearns, Box 942, Dayton Feb. 3-4

Instrument Society of America, National Conference on Chemical and Petroleum Instrumentation, Wilmington, Del. Feb. 3-4

Institute of Radio Engineers, Conference on Transistor and Solid-State Circuits, University of Pennsylvania and Sheraton Hotel, Philadelphia Feb. 20-21

MARCH

American Institute of Chemical Engineers, 1958 Nuclear Congress (Fourth International Atomic Exposition), Palmer House and International Amphitheatre, Chicago March 16-21

Institute of Radio Engineers, 1958 National Convention, New York Coliseum, New York March 24-27

Fourth International Instrument Show, Caxton Hall, Westminster, London, S.W. 1 March 24-29

American Power Conference, 20th Anniversary Meeting, Hotel Sherman, Chicago March 26-28

APRIL

Instrument Society of America (New Jersey section), Tenth Annual Symposium—Control Systems Engineering—Hotel Essex House, Newark, N. J. Program and reservations: Norman Dayton, c/o Norman Bragar Co., 1060 Broad St., Newark 2, N. J. April 1

American Society of Mechanical Engineers, Fourth IRD Conference, University of Delaware, Newark, Del. (Note date corrected from last issue—Ed.) April 2-4

Institute of Radio Engineers, 10th Southwestern Conference & Electronics Show, St. Anthony Hotel and Municipal Auditorium, San Antonio, Tex. April 10-12

American Institute of Electrical Engineers, Automatic Techniques Conference, Hotel Statler, Detroit April 14-16

Electronic Components Conference, sponsored by IRE, AIEE, Ambassador Hotel, Los Angeles. April 22-24

WHAT'S AVAILABLE IN REPRINTS

The following reprints have been prepared to make important reference-type editorial material available to CONTROL ENGINEERING readers in convenient filable form. Some reprints are individual articles, while others are "packages"—several articles published over a period of time that logically supplement one another in the coverage of a specific phase of the control field. Any reprint can be obtained at the nominal cost listed below by filling in the order form and sending it, together with remittance, to Readers Service Dept. Quantity rates will be quoted on request.

Survey of Numerically-Controlled Point-to-Point Positioning Systems—II, February 1958, 24 pp. The second of three parts, this article continues with detailed descriptions of ten machine tool systems. 50 cents.

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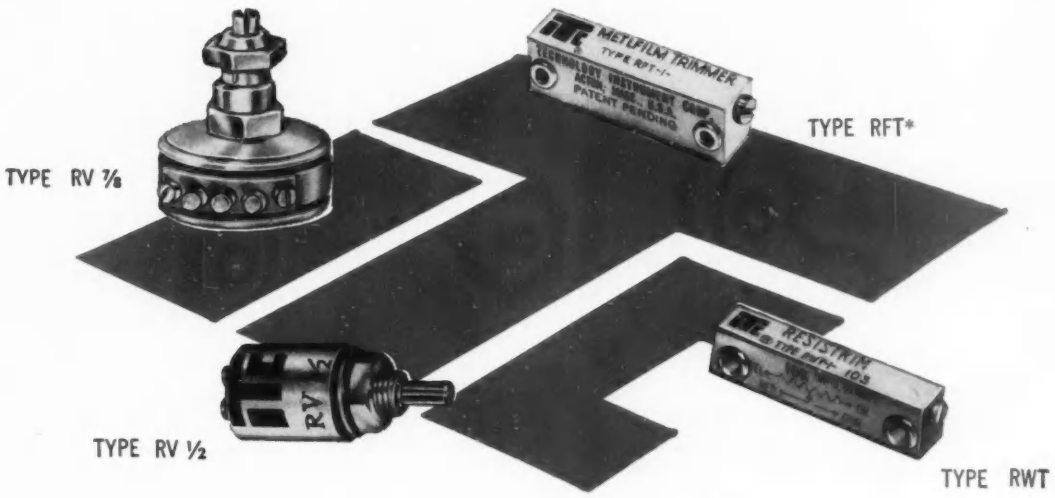

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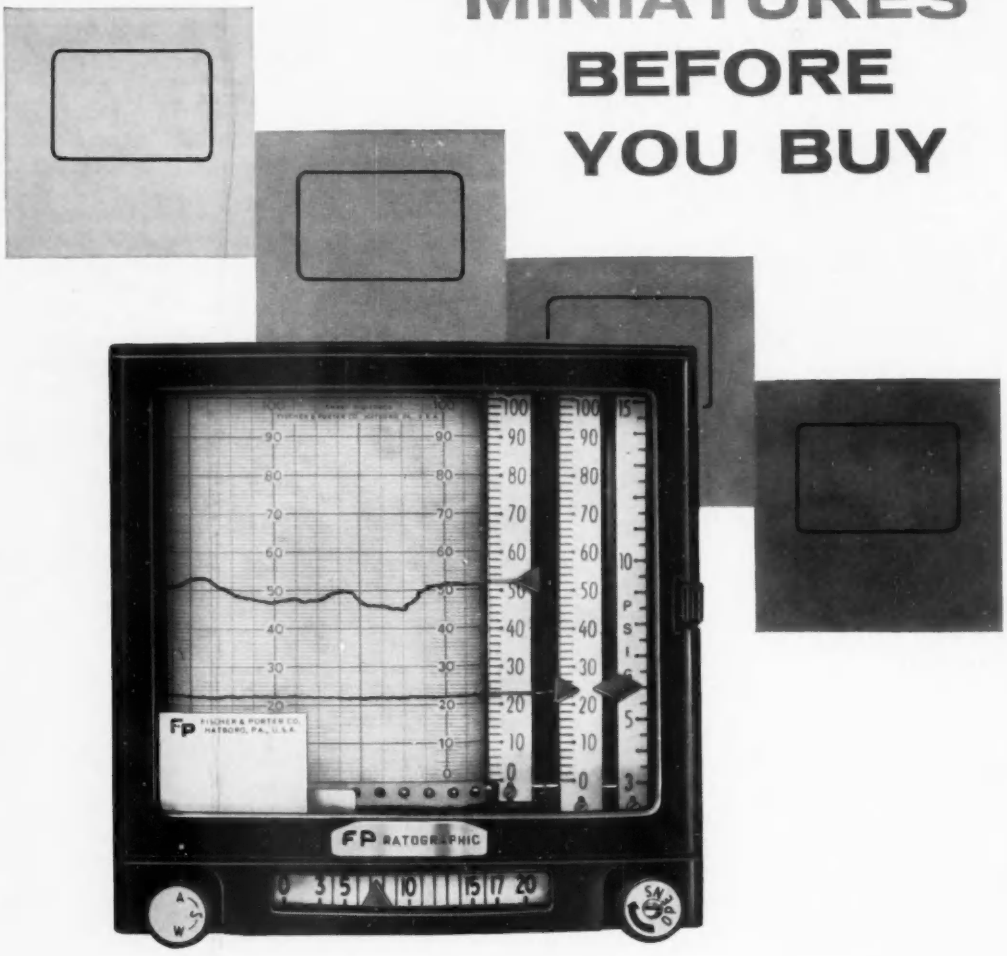

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